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ECOLE POLYTECHNIQUE DE MONTREAL

By AUGUSTIN FRIGON

Dean of l'Ecole Polytechnique

Greater Montreal, according to 1928 estimates, has a population of 1,224,039 of which approximately 75 per cent is French-speaking. This makes Montreal the second largest French-speaking city in the world. It is not surprising, therefore, to find here a French university, the "Université de Montréal" with a total enrolment in 1928–29 of 6,638 students and a staff of 601 professors. This university used to be the Montreal branch of "l'Université Laval" of Québec, founded in 1852. As the Montreal group had become much more important than the mother institution, it obtained its own charter and was reorganized in 1920 under the name of "Université de Montréal." As it exists at present, "l'Université de Montréal" is composed of a certain number of faculties, of affiliated and of annexed schools. "l'Ecole Polytechnique" is one of the affiliated schools, and is in fact the applied science faculty of that university. It had some 190 students last year with a staff of thirty-one professors and lecturers.

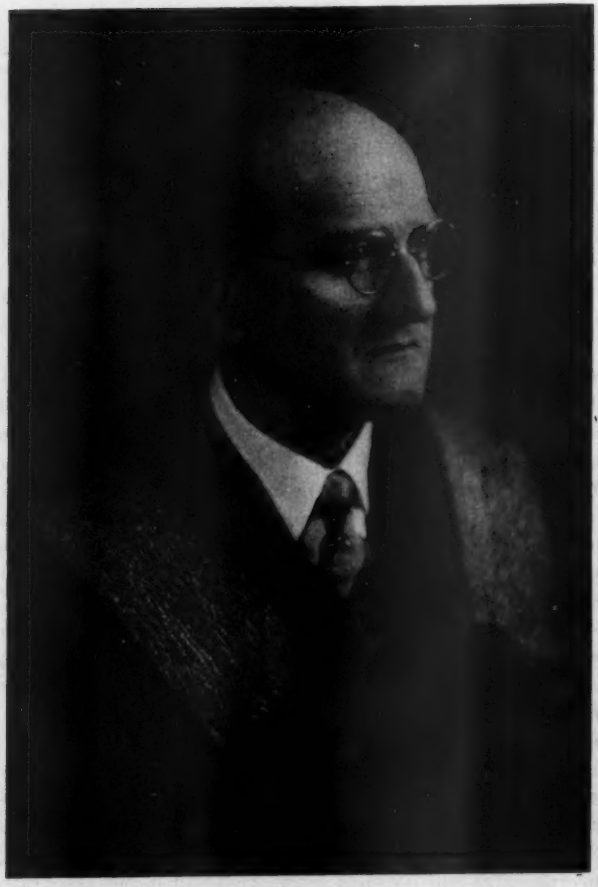
"L'Université de Montréal" cannot boast of an imposing campus, its different buildings and affiliated schools being scattered over a certain district of the city. However, a very imposing building is now under construction on the western slope of Mount Royal, which, when completed, will house the medical faculty with a 480-bed teaching hospital, the pure science faculty, the dental faculty, the school of pharmacy, the general library and the general administrative quarters of the University, as well as a certain number of rooms for other faculties and smaller departments. This huge building, 1,400 feet long by 450 feet deep, six stories high, with its numerous wings designed in such a way as to allow easy

UNIVERSITÉ DE MONTRÉAL.
(Under construction.)

extensions, is located at the west end of a magnificent property, 3,500 feet long by 1,500 feet deep, covered with century-old trees and overlooking, from an elevation of a couple of hundred feet, the western and northern part of the island of Montreal, with the Laurentian Hills as a background. We are proud to say that the architect and engineer of this most elaborate and remarkably well designed educational institution is a graduate of "l'Ecole Polytechnique," Mr. Ernest Cormier who, after graduating with us in 1906 went to "l'Ecole des Beaux-Arts" in Paris where he obtained his degree in Architecture from the government of France.

"L'Ecole Polytechnique" was founded in 1873. A French chemist, Mr. Charles Pfister, then professor of science at one of the classic colleges near Montreal; Mr. Urgel Eugène Archambault, Principal of the leading catholic primary school in Montreal, and Mr. Gédéon Ouimet, Minister of Education of the Province of Quebec, must be credited with having conceived the idea of and of having organized this school. The first director of studies to take charge of the school was a French gentleman, Col. Emile Balète, who had won many laurels in the Franco-Prussian war of 1870. This engineering school is owned and administered by the "Corporation de l'Ecole Polytechnique de Montréal" which is composed of representatives of the Government of the Province of Quebec, of the primary catholic schools system, of the "Université de Montreal and of engineers selected amongst the graduates of the school. The capital invested in the buildings and equipment is guaranteed by the Government of the Province of Quebec, and the main source of revenue of the school is an annual subsidy from that same government. In some respects Ecole Polytechnique is therefore a state school of engineering, although it is quite independent of all governmental and political interference in its administration.

According to a contract of affiliation to the "Université de Montréal," the degrees to which the students of "l'Ecole Polytechnique" are entitled are given to them by the University upon the request of the school. Besides, the appoint-



AURÉLIEN BOYER,
PRINCIPAL OF "ECOLE POLYTECHNIQUE" of Montreal.

ment of the staff of the school is to some extent subject to the formal approval of the Chancellor of the University. "L'Ecole Polytechnique" is, however, absolutely free of all restrictions in regards to its programs, conditions of admission, methods of teaching, etc. The Corporation of "l'Ecole Polytechnique" is also represented on different committees of the "Université de Montréal."

"L'Ecole Polytechnique" is located in quite a strategic point of the French section of Montreal, just above St. Catherine street on St. Denis street. Its main building, with frontage on a small square opposite one of the finest churches in Montreal, has a total floor area of 56,000 sq. ft., and an annex, containing different laboratories, drawing rooms and a small gymnasium, has a floor area of 22,000 sq. ft. As the property extends across a city block to Sanguinet street, land is available for further extension. The present main building was built in 1904 but the top story was added to it in 1917. The annex was built in 1907. Up to the present time this school has devoted all its energy to teaching and very little research has been done in its laboratories outside of the necessary work of this nature done by the students. The laboratories are fully adequate for the purpose they serve, and besides the usual physics and chemistry laboratories they include modern equipment for testing materials, and a special laboratory for testing oils, asphalts and other inorganic matters of that character. There is also a good geology and mineralogy museum and a very fine technical library. The general library of the Université de Montréal is also, of course, at the disposal of those connected with the school. According to special arrangements the very fine shops of the Montreal Technical School are used for the few hours in manual training which each student must do; so is the very modern power plant of that institution, for different tests in thermodynamics.

Approximately sixty-five per cent of the students of "l'Ecole Polytechnique" are Montrealers. The others belong to the rest of the Province of Quebec with the exception

of a few which come from French centers in other provinces and even from the United States. With only very few exceptions the students of Ecole Polytechnique are all French-speaking and their professors are either French Canadians, or gentlemen who have been engaged in France and Belgium. All lectures are given in the French language, but most of the textbooks used in the appliel science courses and even in some pure science courses are English, edited either in England or in the United States. The use of English textbooks rather than French was found preferable in order to initiate the students to the American practice in engineering followed in Canada, and also to give them the opportunity to acquire a better working knowledge of English. All students of course know the English language very well, and many of them can speak it fluently.

Up to a few years ago, most of the graduates of "I'Ecole Polytechnique" specialized in public works after graduation, so that at present they have practically complete control of municipal, provincial and federal public works in the Province of Québec, and a great many of them hold important positions in municipal and federal public services in other provinces. Conditions have changed, however, and now most of them are seeking positions in varied industrial branches. This new policy has opened a new field to our graduates; firms which have engaged some of them recently come back for more recruits and the result is that we cannot supply half the demand. We believe that the fact that we give to our students a general education in applied science, which enables them to specialize very easily in any branch, once they are engaged in actual engineering practice, is helping our graduates a good deal to secure positions and hold those positions with success in a great many branches of engineering. The very fact that after having been successful in public works they now have the same success in industrial fields although no fundamental changes have been made to our curriculum, seems to prove the superiority of general education as compared to specialized training. The fact that

all of them are strictly bilingual also represents a certain advantage in many cases, specially in this bilingual country. Although a good many of our students have done some post-graduate work in some of the best engineering schools of United States and Europe, only a few have left Canada permanently.

The Province of Québec is very prosperous and its industries are developing very rapidly. "L'Ecole Polytechnique" is therefore confident of enjoying a growing popularity and effectiveness. The Government of the Province of Québec understands the situation and is helping as much as it possibly can.

FREE INFORMATION ON CANADA

For the benefit of members and friends of the Society for the Promotion of Engineering Education, who contemplate attending the Convention of this organization which is to be held in Montreal, Canada, June 26–28, 1930, we wish to announce that, according to advice received, information on Canada's recreational attractions may be had without charge from the Natural Resources Intelligence Service, Department of the Interior, at Ottawa, Canada.

This Service also issues for free distribution a series of automobile road maps consisting of four sections, showing the main highways in Canada and the northern States, namely, the Atlantic, Great Lakes, Middle West and Pacific Sheets. The sketch map reproduced on this page indicates the area covered by one of these maps, which, however, contains much more detail than can be shown here.

ONTA
Port Arthur
Fort William
MINN
LAKE SUPERIOR
WISCONSIN
MICHIGAN
CHICAGO
DETROIT
ILLINOIS
INDIANA
Cincinnati
ST LOUIS
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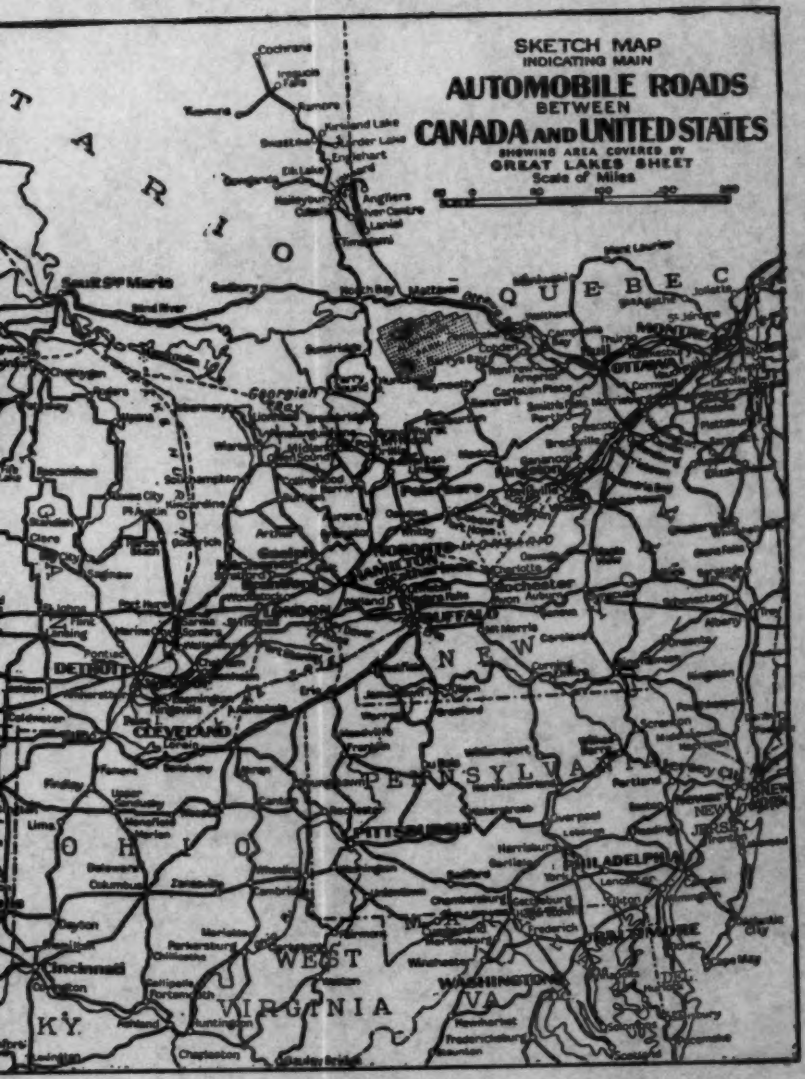

SKETCH MAP
INDICATING MAIN
AUTOMOBILE ROADS
BETWEEN
CANADA AND UNITED STATES
SHOWING AREA COVERED BY
GREAT LAKES SHEET
Scale of Miles
ONTARIO
QUEBEC
NEW
PENNSYLVANIA
OHIO
WEST
VIRGINIA
KY.
VA.
DETROIT
CLEVELAND
BUFFALO
PHILADELPHIA
WASHINGTON
Cochrane
Sault Ste Marie
North Bay
Sudbury
Toronto
Hamilton
London
Ottawa
Montreal
Rochester
Pittsburgh
Cincinnati
Columbus
Chicago

EMPLOYMENT SERVICE

To the Members of the Society:

In order that the Society may be of further assistance to you, we are compiling a list of the vacancies which will be open in the engineering schools of the United States and Canada next year.

If you desire to make a change in your position, please send to us the type of position you wish; the section of the country in which you prefer to live; the salary expected. We should also have full information concerning your qualifications so that we may refer these to the institution seeking a man of your ability.

All information received in response to this notice will be kept confidential and sent only to institutions where there is an opening which will benefit you.

This information should be in our hands at once as appointments for next year will be made within the next two months.

Very truly yours,

F. L. BISHOP,
Secretary

ENGINEERING EDUCATION

Suggested Methods for Developing Mental Qualities Required of Engineers

By A. R. KNIGHT

Assistant Professor of Electrical Engineering, University of Illinois, Urbana, Illinois

The question is often asked by the students, the instructor, and the industries, "What can be done better to prepare the student for his engineering work?" The various suggestions offered in answer to this question are in the main of two general types, one being to divide the students into two groups, giving to the average man a training which will fit him for work as a technician, and to the superior man a *real* engineering training; the other being to extend the time required for obtaining a degree and to include in the course more work of a broadening nature.

The technical schools are now trying to give a *real* engineering training and the suggestion that the men be divided into two groups leaves the question of how the superior man is to be handled as obscure as it is at present. Regarding the second suggestion it need only be pointed out that if the present method of training is not productive of the desired result that it is not likely that a longer period of the same kind of training will be any more successful.

I do not believe that it is so much a question of the length or content of the course as of the viewpoint of the student and the instructor. It is a common belief among students that the object of their college work is the accumulation of facts which they are going to sell to an employer after graduation. This belief is strengthened in many class rooms by the emphasis laid by the instructor upon formula merely as formula. The purchase of a suitable library will supply far

more facts than any student can hope to acquire but no one would think of such a proceeding as producing an engineer. It follows then that the engineer should have the ability to *use* facts and that the development of this ability should be the object of the schools.

There are four important mental qualities needed for successful engineering work, namely, reasoning power, comprehension, memory, and concentration, and I believe that if the student can be made to realize that it is training in these things that he is after that his progress will be much more rapid and satisfactory.

I have used the methods outlined below for a number of years and think that they have some merit.

Reasoning.—The discussion of the physics of any machine or circuit gives an excellent medium for this development. The student must be made to prove conclusively that the machine or circuit behaves as it does because it *cannot do otherwise* and not because some formula indicates what the action should be. It must be emphasized at all times that any formula is merely a short hand method of expression.

The solution of problems also offers an excellent medium. In order to be of the greatest benefit the solution of the problem should be divided into two parts, one, which may be called the qualitative solution, which outlines the steps in reasoning by which the desired result is to be obtained from the given data, and the authority for each step. The second part, which may be called the quantitative solution, merely substitutes the numerical values given into the steps outlined in the qualitative solution and thus leads to a numerical result.

Illustrative Problem

A shunt motor connected to a 115 volt source and running without load takes a field current of 2.8 amperes and an armature current of 3.0 amperes. When the armature is blocked an impressed e.m.f. of 5.5 volts is required to produce the load current of 50 amperes through it. What are the resistances of the field and the armature windings and

what is the counter e.m.f. generated in the armature when the motor is taking full load current.

Qualitative Solution

Given: (1) Type of motor,
(2) Rating of motor,
(3) Current taken by field and armature at no load,
(4) Voltage required to send full load current through the blocked armature.

To find: (1) Resistance of the field,
(2) Resistance of the armature,
(3) Generated e.m.f. of the armature at full load.

Method: Find resistance of field by dividing the e.m.f impressed by the current,

Authority: Since the machine is a shunt motor the line voltage is impressed on the field. Use the statistical relation between current, voltage and resistance given by Ohm's Law.

Find resistance of armature in same manner as field. Same authority as for field plus the fact that with the armature blocked there is no generated e.m.f. and the circuit is a simple resistance.

Find counter e.m.f. at full load by subtracting the IR drop in the armature from the impressed e.m.f. Authority—Kirchoff's Law, which says that the sum of the potential drops around any closed loop equals zero. In this case the impressed e.m.f. equals the sum of all potential differences in the armature circuit.

There are but two causes of potential difference in the armature so that if one is known the other can be found.

Quantitative Solution

$$R_f = \frac{115}{2.9} = 41.1 \text{ ohms},$$

$$R_a = \frac{5.5}{50} = .11 \text{ ohm}.$$

At full load the IR drop in the armature is $50 \times .11$ or 5.5 volts. Generated e.m.f. is 115 — 5.5 or 104.5 volts.

Comprehension: It has been my experience that the majority of students do not fully grasp what they read or hear. To overcome this difficulty require the student to read a paragraph of the text and then express the content in his own words, reading the paragraph as many times as is necessary to accomplish it. It will help the student in this work if it is pointed out to him that each paragraph has one central idea and that all other statements contained in it are either introductory or explanatory. Short news items of technical interest may be read to the class and then written upon by the student. To be the most effective the work should be handed to the instructor for examination and criticism.

Memory: Little need be said regarding this subject since the memory is being called into play constantly. It may be said in passing, however, that definitions and units offer excellent material for this training.

Concentration: The development of this ability is almost entirely in the hands of the student although help may be given by the instructor. There is no difficulty on the part of the student in concentrating when doing written work in the classroom. The reason is that he realizes that he has a definite amount of work to do in a definite time. He can then increase his concentration while studying at home by duplicating the classroom conditions, that is, divide his work up into definite portions and set definite time limits for their completion. It has been found that this works very well in conjunction with the analysis of paragraphs for the central idea referred to above.

I have frequently asked the students to report upon the time required to analyze the paragraphs in an assignment and have been surprised to find that the parts which I thought would present difficulty were handled in a short time and those which I thought would be easy frequently required considerable time. It has been beneficial in my case to do this occasionally in order to keep me in sufficiently close touch with the viewpoint of the student.

ECONOMICS OF ENGINEERING *

By WILLIAM D. ENNIS

Alexander Crombie Humphreys Professor of Economics of Engineering, Stevens Institute of Technology

It will be convenient to visualize our subject in its obvious and even less obvious *relationships.*

Practically all engineering schools—I know of no exception, except possibly Cooper Union—have *courses* in engineering economics or industrial engineering, or management, or some apparently related subject. (The *name* "engineering economics" is used in only four or five institutions.) A few of the schools (Boston Tech, Lehigh, Penn State, Rutgers, Columbia, New York University †) go farther and have *curriculums* in engineering administration or industrial engineering, giving this subject the same rank and emphasis, for example, that they do mechanical engineering. Somewhat less obviously associated with the field are *schools of business,* such as those at Columbia, Harvard, New York University, Northwestern University and University of Pennsylvania.

Where engineering economics or an equivalent subject is given as a course—by far the more common arrangement—it rarely claims the rank of a *department,* in the sense in which power engineering is a department. At Brooklyn Polytechnic, for example, Works Management is a course given by the department of Mechanical Engineering. At Stevens, by contrast, Economics of Engineering is a department just as much as is Chemistry or Physics.

* Paper prepared for the winter meeting of the Middle Atlantic Section of the S. P. E. E., held at the Bell Telephone Laboratories, December 14, 1929.

† Industrial Engineering option in the Mechanical Engineering Curriculum.

The three types of instruction thus existing (course, curriculum or school) have their common foundations in formal economics, accounting and production management. Formal economics and formal accounting are quite apt to be contributions from other than the engineering departments. There may in some cases be, in fact, no special coordination of these subjects. Such coordination is presupposed where economics of engineering is to have the rank of a department. At Rutgers the curriculum in Industrial Engineering includes eight courses given by the college department of Economics, a course in industrial organization given by the department of Mechanical Engineering, and a semi-elective course in engineering economics given by the department of Civil Engineering. At Columbia, the graduate curriculum in Industrial Engineering (leading to the degree of Master of Science) seems to be under joint auspices of the School of Engineering and the School of Business.

The time has not yet come when it is possible to state a single basic conception about which these courses are built. There is nothing in our subject analogous to Ohm's law in electrical engineering, to the laws of thermodynamics in power engineering, or to Newton's laws of equilibrium and motion in structural and machine engineering. Economics of engineering is really not a subject at all: it is a point of view.

On the other hand, it is not at all difficult to state the text about which a particular subject, like accounting, is written. I will even be venturesome enough to hazard a statement, in 43 words:

> Record every business transaction in two equal money quantities. Credit him who gives and debit him who receives. If related to closed transactions, debits are expenses and credits are revenues: if to transactions not yet closed, debits are resources and credits are liabilities.

It is recorded that Mark Hanna once remarked at a dinner party in Washington that the invention of double entry bookkeeping was a great intellectual achievement. It was Henry

Adams who relieved the somewhat supercilious atmosphere which followed by reminding the party that Goethe had said the same thing.

In the hope of starting a profitable discussion, I will attempt, in the second place, to write the text of the general subject of formal economics. It is:

> the investigation of those modes of sharing the results of production (among the agencies contributing thereto) which react most favorably on the aggregate of production.*

It is still more difficult to define production management. Perhaps we may say it involves the determination and control of productive efficiency; with the qualification sometimes added, "inside the factory door."

Twenty-five or thirty years ago we were all talking about the application of engineering methods to production management. Production was the first branch of business to have thorough engineering attention. Today, however, we are talking in more modest terms, of the application of business methods in engineering: and this gives me courage to suggest an inner idea, if not the absolutely central idea, of engineering economics. It is this: that business is becoming a profession.

At Stevens the name which President Humphreys originally gave the course was Business Engineering (business in engineering). It remains that today: the application of business principles—that is, economic principles—to engineering problems. It is economics *in* engineering. Where an engineering situation involves economic factors—that is, business or commercial factors—there we belong. If there is a problem of engineering practice which does not involve such factors, I have not encountered it. Our men must have at least as much respect for, and acquaintance with, the dollar sign as for, and with, the sign of integration; and there are thousands of ways to bring in the dollar sign.

* My colleague, Professor Barnwell, proposes the alternate text: a study of the distribution of income among the (scarce) agents of production, and of the forces which cause such use of these agents as will result in the greatest aggregate of production.

Our problem is that of the teacher of any engineering subject—*what* to teach and *how* to teach: but this problem has special difficulty for us. We have a field without definite limits: a field which is constantly, rapidly and permanently growing: and we have a type of student who, to some extent, has the wrong prepossessions. As Mr. Piez, the new President of the A. S. M. E. has stated, the engineer, and particularly the engineering student, is little interested in matters like the tariff, the Federal Reserve Act and chain stores. He is "addicted too much to formulæ and too little to observation." He lacks power of interpretation and expression, and even his vocabulary is abnormally limited. I suspect that in many cases he rarely reads a newspaper.

We have not reached standardization of subject matter; and I hope and believe we never will. There is and should be considerable variety in what we teach. At Stevens just now, for example, we are beginning some inquiries into (*a*) the commercial side of transportation by air and (*b*) an approach to the process of invention by way of market study. These are highly specialized topics. We may have them all to ourselves for a while. Other schools will specialize on other subjects, and that is as it should be. These special inquiries derive their maximum value from the fundamental principles which they are bound to illustrate. I will even go farther and preach stark heresy: that what is taught in economics of engineering in any particular institution should and will depend rather largely on the experience and special interests of the teacher.

Professors Fish and Grant out at Stanford University and the latter at University of Montana have actually established a "clearing house" for problems in engineering economics; largely, I take it, in recognition of this idea. I myself am devoting a very substantial part of my class time to public utility valuations and rate making and am prepared to contend in favor of that policy. Others—perhaps many others—will concentrate on standards, wage systems, time study.

It seems to me that one of the big opportunities we have is to stress the economic importance of manufacturing. Our

men do not realize that importance and I venture to say that many engineers do not. The annual value of products of the factories of this country, omitting duplications, is more than twice the value of farm products, more than four times the operating revenues of railroads, just about five times the value of mineral products and over ten times the value of output from public utility electric and gas plants. Considering the proportion of technical graduates who enter such fields as transportation and public utilities, manufacturing has been neglected.

I believe it will lend itself to the most spirited discussion if I now submit a 13-point statement of principles; without much argument, although I am not averse to the argument if time permits. Let us nail these thirteen theses, if you please, to the door of the cathedral as subjects at which to shoot:

1. Maximum return will be derived by teaching economics of engineering not as a curriculum in itself, but as a department of curriculums in civil, electrical or mechanical engineering.

2. The work of such department, including its work in accounting and economics, should preferably be organized by an engineer.

3. Organizing economics of engineering as a department, there will be several subjects for teaching. No one text-book, available or likely to be available, will cover all of these subjects.

(Fish's "Engineering Economics" was one of the first attempts at a generalization. "Management's Handbook" remains excellent for other than fundamental subjects. Dean Kimball's "Industrial Economics" furnishes a substantial background. Prof. Grant's "Principles of Engineering Economy," to be issued by The Ronald Press Co., early next year, makes a distinct step toward basic principles).

4. We should explore all subdivisions of the engineering field—civil, electrical, mechanical and other—for our illustrations.

5. Instruction should be based on actual, not hypothetical cases.

6. The course should touch non-engineering subjects and problems, at least in relation to the production department (narrowly so-called), and probably in and for themselves as well. We should be generous in our delimitation of the field; prepared to study city land values, resale price control and dumping, for example, as well as the most economical span for a bridge.

7. The teaching of production management is likely to be the point of chief difficulty; on account of its magnitude, rapid growth and remoteness from the student; and because of wide differences in teaching points of view.

8. It would be premature to attempt, as yet, anything approaching standardization of courses with respect to content. Perhaps we could not agree even on standardization of *elements* in courses. This year in formal economics with our seniors, we are completely omitting the subject of international exchanges. We may change our minds within a year or two.

9. The subject should be given with a strongly humanistic flavor, free from artificial and deceptive rigor and stressing the faculties of interpretation and expression.

10. The matter of professional ethics should be brought in incidentally and persistently, but not systematically: that is, we should not include any formal examination of codes.

11. The bulk of the work should be done in the senior year.

12. Earlier than senior contact is desirable in addition.

13. Most institutions will probably find it easier to provide for the first contact with the subject in the sophomore rather than in any other year.

This suggests a topic on which I am not prepared to make a recommendation or nail a thesis to the door; a question which it would be helpful to discuss and (if possible) answer at this session, namely; what particular kinds of subject matter are likely to be most useful and practicable in the sophomore year?

THE 1930 SESSIONS OF THE SUMMER SCHOOL FOR ENGINEERING TEACHERS

By H. P. HAMMOND, *Director of Summer Schools*

Announcements of the two sessions of the Summer School of 1930 were made in the September and December, 1929, issues of the JOURNAL. The staffs of the two sessions have now been selected and the programs are virtually complete. They are printed below for the information of the Society membership.

CIVIL ENGINEERING SESSION

As previously announced, the session on civil engineering will be held at Yale University from July 1 to 23, inclusive. This will permit members who are expecting to attend the annual convention of the Society to go directly from Montreal to New Haven and arrive in time for the beginning of the session.

Three days of the session will be spent at the Yale Engineering Camp at East Lyme, Connecticut; one day, the last of the session, will be devoted to a trip of inspection to engineering works in progress in New York City; the remaining days will be spent on the campus at New Haven.

The summer school group will be housed in the dormitories of the University, and meals will be provided for the entire party at a central dining hall. The usual registration fee of ten dollars will be charged. The cost of room and meals will be about seventeen dollars per week.

The attendance at the session will be limited to one hundred. At the date of writing (March 15) fifty-two applications are on file.

The program of the civil engineering session has been arranged in two parts, one common to all of the members, the other arranged in three divisions, relating respectively to

structural engineering, to sanitary and hydraulic engineering, and to highway and railway engineering. The general portion of the program will deal with principles and methods of teaching, with the aims and purposes of civil engineering education and of its principal divisions, with professional ethics and practices, with engineering materials, and with other topics of interest to all teachers of civil engineering. The other divisions will relate more specifically to the teaching of the subjects of instruction that constitute the civil engineering curriculum.

The civil engineering session is being sponsored by the American Society of Civil Engineers and the program has been arranged in cooperation with an advisory committee of that Society. The Highway Education Board and the Portland Cement Association have also cooperated in supporting the session and in advising concerning the program. The list of staff members and the program follow.

STAFF

LOCAL DIRECTOR OF THE SESSION: John C. Tracy, Professor of Civil Engineering, Yale University.

SECRETARY: Roscoe H. Suttie, Associate Professor of Civil Engineering, Yale University.

GENERAL DIVISION

William Bowie, Chief, Division of Geodesy, U. S. Coast and Geodetic Survey
Charles S. Farnham, Associate Professor of Civil Engineering, Yale University
James K. Finch, Professor of Civil Engineering, Columbia University
Alfred D. Flinn, Director, Engineering Foundation
H. F. Gonnerman, Laboratory Manager, Portland Cement Association
J. W. Kelly, Engineer, Portland Cement Association
Philip G. Laurson, Associate Professor of Engineering Mechanics, Yale University
F. R. McMillan, Director of Research, Portland Cement Association
Anson Marston, Dean of Engineering, Iowa State College.
C. H. Mathewson, Professor of Metallurgy and Metallography, Yale University
C. W. Mayers, Chief Engineer and Vice-President, Morton C. Tuttle Company
Herbert F. Moore, Research Professor of Engineering Materials, University of Illinois
R. S. Phillips, Engineer, Portland Cement Association
Elliott D. Smith, Professor of Industrial Engineering, Yale University
Francis T. Spaulding, Associate Professor of Education, Harvard University
Charles M. Spofford, Professor of Civil Engineering, Massachusetts Institute of Technology
Charles S. Whitney, Consulting Engineer

STRUCTURAL DIVISION

O. H. Ammann, Chief Engineer of Bridges, The Port of New York Authority
George E. Beggs, Associate Professor of Civil Engineering, Princeton University
Almon H. Fuller, Professor of Civil Engineering, Iowa State College
William K. Hatt, Head, School of Civil Engineering, Purdue University
O. E. Hovey, Assistant Chief Engineer, American Bridge Company
Clarence W. Hudson, Consulting Engineer
Frank P. McKibben, Consulting Engineer
Clyde T. Morris, Professor of Civil Engineering, Ohio State University
D. B. Steinman, Consulting Engineer
Frederick E. Turneaure, Dean, College of Engineering, University of Wisconsin
J. A. L. Waddell, Consulting Engineer
Francis P. Witmer, Professor of Civil Engineering, University of Pennsylvania

SANITARY AND HYDRAULIC DIVISION

Charles M. Allen, Professor of Hydraulic Engineering, Worcester Polytechnic Institute
William P. Creager, Vice-President and Chief Engineer, Northern New York Utilities, Inc.
Gordon M. Fair, Associate Professor of Sanitary Engineering, Harvard University.
T. Chalkley Hatton, Consulting Engineer
Thaddeus Merriman, Chief Engineer, Board of Water Supply, New York City
Richard G. Tyler, Dean, College of Engineering, University of Washington
Elton D. Walker, Professor of Civil Engineering, Pennsylvania State College
Robert Spurr Weston, Consulting Engineer
Sherman M. Woodward, Professor of Mechanics and Hydraulics, State University of Iowa

HIGHWAY AND RAILWAY DIVISION

Thomas R. Agg, Professor of Highway Engineering, Iowa State College
A. G. Bruce, Engineer, U. S. Bureau of Public Roads
Samuel Eckels, Chief Engineer, State Department of Highways, State of Pennsylvania
George B. Ford, Director, Regional Plan of New York
Maxwell Halsey, Traffic Engineer, Department of Public Works, Commonwealth of Massachusetts
Arthur G. Hayden, Designing Engineer, Westchester County Park Commission
Fred Lavis, Consulting Engineer
Roger L. Morrison, Professor of Highway Engineering and Highway Transport, University of Michigan
J. E. Slater, Consulting Engineer
Clement C. Williams, Dean, College of Engineering, State University of Iowa

PROGRAM

TUESDAY, JULY 1

1:30 P.M. Introductory Remarks
Charles H. Warren, J. C. Tracy, H. P. Hammond
2:30 P.M. The Aims and Purposes of Civil Engineering Education
Anson Marston
3:15 P.M. Psychology of the Learning Process .....F. T. Spaulding
Evening: Smoker

WEDNESDAY, JULY 2

8:45 A.M. General Principles of Teaching .....F. T. Spaulding
10:00 A.M. Professional Ethics and Practices .....Anson Marston
11:00 A.M. Research in Civil Engineering .....Alfred D. Flinn
1:30 P.M. Inspection of Yale Campus

THURSDAY, JULY 3

8:45 A.M. A résumé of the History of Civil Engineering of the Eighteenth Century .....Anson Marston
10:15 A.M. Classroom Methods .....F. T. Spaulding
1:30 P.M. Examinations and Tests .....F. T. Spaulding
3:30 P.M. Party leaves for the Yale Engineering Camp
7:00 P.M. Inspection of Yale Camp Buildings
8:30 P.M. The Yale Engineering Camp .....J. C. Tracy

FRIDAY, JULY 4

OUTINGS AT THE CAMP AND AT THE SEASHORE

SATURDAY, JULY 5

8:45 A.M. Organization, Purposes and Scope of Courses in Surveying
J. K. Finch, J. C. Tracy
10:15 A.M. Classroom and Field Methods in Surveying
J. K. Finch, C. S. Farnham
1:30 P.M. Personal Problems and Adjustments of Students F. T. Spaulding
3:00 P.M. Progress in the Art of Surveying.....William Bowie

SUNDAY, JULY 5

3:30 P.M. Party returns to New Haven

MONDAY, JULY 7

8:45 A.M. Purposes, Content and Scope of Courses in Structural Engineering .....F. E. Turneaure
10:15 A.M. Purposes, Content and Scope of Courses in Sanitary and Hydraulic Engineering .....Elton D. Walker
1:30 P.M. Purposes, Content and Scope of Courses in Highway and Railway Engineering .....C. C. Williams

TUESDAY, JULY 8

8:45 A.M. Divisional Meetings

Structural Division	*Sanitary and Hydraulic Division*	*Highway and Railway Division*
Discussion: Teaching Mechanics of Materials; Flexure	Discussion: Teaching Hydraulics; Hydrostatics	Discussion: Teaching Highway Engineering; Location and Design
A. H. Fuller	S. M. Woodward	T. R. Agg

10:15 A.M. Teaching Economics of Engineering .....C. C. Williams
1:30 P.M. Business Relations in Civil Engineering Practice; Contracts and Specifications .....C. M. Spofford
7:30 P.M. Teaching Personnel Administration .....Elliott D. Smith

WEDNESDAY, JULY 9

8:45 A.M. History of Bridge Construction ..... P. G. Laurson

10:15 A.M. Divisional Meetings

Structural Division	*Sanitary and Hydraulic Division*	*Highway and Railway Division*
Discussion: Teaching Mechanics of Materials; Simple and Combined Stresses A. H. Fuller	Discussion: Teaching Hydraulics; Hydrokinetics S. M. Woodward	Discussion: Teaching Highway Engineering; Materials T. R. Agg

THURSDAY, JULY 10

8:45 A.M. Divisional Meetings

Structural Division	*Sanitary and Hydraulic Division*	*Highway and Railway Division*
Discussion: Teaching Mechanics of Materials; Columns A. H. Fuller	Discussion: Teaching Hydraulics; Hydrodynamics S. M. Woodward	Discussion: Teaching Railway Economics C. C. Williams

10:15 A.M. History of the Flexure Formula ..... H. F. Moore

1:30 P.M. Divisional Meetings

Structural Division	*Sanitary and Hydraulic Division*	*Highway and Railway Division*
Discussion: Teaching Structural Engineering; Statically Determinate Structures, Fixed Loads F. E. Turneaure	Discussion: Teaching Water Supply Engineering; Collecting Works Elton D. Walker	Discussion: Teaching Highway Engineering; Surfaces T. R. Agg

FRIDAY, JULY 11

8:45 A.M. Elastic Properties of Materials ..... H. F. Moore

10:15 A.M. Divisional Meetings

Structural Division	*Sanitary and Hydraulic Division*	*Highway and Railway Division*
Discussion: Teaching Structural Engineering; Statically Determinate Structures, Moving Loads F. E. Turneaure	Discussion: Teaching Water Supply Engineering; Treatment Works Elton D. Walker	Discussion: Teaching Highway Engineering; Materials Testing T. R. Agg

1:30 P.M. Behaviour of Materials under Repeated Stresses.... H. F. Moore

7:30 P.M. Lecture ..... (Speaker to be announced)

SATURDAY, JULY 12

8:45 A.M. Divisional Meetings

Structural Division	*Sanitary and Hydraulic Division*	*Highway and Railway Division*
Teaching Structural Engineering; Statically Indeterminate Structures Francis P. Witmer	Teaching Water Supply Engineering; Distribution Works R. G. Tyler	Teaching Highway Engineering; Highway Transport R. L. Morrison
10:15 A.M. Courses in Structural Design Clyde T. Morris	Teaching Sewerage; Sewer Design R. G. Tyler	Teaching Highway Engineering; Highway Administration R. L. Morrison

MONDAY, JULY 14

8:45 A.M. Enrichment of Experience in the Development of the Engineering Teacher ..... J. C. Tracy
10:15 A.M. Basic Principles of Concrete Making ..... F. R. McMillan
1:30 P.M. Materials for Concrete Making ..... J. W. Kelly

TUESDAY, JULY 15

8:45 A.M. Divisional Meetings

Structural Division	*Sanitary and Hydraulic Division*	*Highway and Railway Division*
Teaching Structural Engineering; Foundations C. C. Williams	Teaching Sewerage; Sewer Construction R. G. Tyler	Organization and Teaching Advanced Courses in Highway Engineering T. R. Agg

10:15 A.M. Production of Durable Concrete ..... F. R. McMillan
1:30 P.M. Proportioning of Concrete ..... R. S. Phillips

WEDNESDAY, JULY 16

8:45 A.M. Divisional Meetings

Structural Division	*Sanitary and Hydraulic Division*	*Highway and Railway Division*
Wind Stresses Clyde T. Morris	Principles and Methods of Water Treatment Robert Spurr Weston	Teaching Highway Traffic Control R. L. Morrison
10:15A.M. Mechanical Methods of Stress Analysis George E. Beggs	Teaching Sewerage; Sewerage Treatment Gordon M. Fair	Highway Administration and Finance Samuel Eckels

THURSDAY, JULY 17

8:45 A.M. Divisional Meetings

Structural Division	*Sanitary and Hydraulic Division*	*Highway and Railway Division*
Movable Bridges O. E. Hovey	Teaching Sewerage; Sewage Treatment Gordon M. Fair	Economics of Railway Location Fred Lavis

10:15 A.M. Research in Concrete ..... H. F. Gonnerman
1:30 P.M. Manufacture of Concrete ..... J. W. Kelly

FRIDAY, JULY 18

8:45 A.M. Divisional Meetings

Structural Division	*Sanitary and Hydraulic Division*	*Highway and Railway Division*
Principles of Arch Analysis C. W. Hudson	Sanitary Biology Gordon M. Fair	Economics of Highway Design A. G. Bruce
10:15 A.M. Economics of Bridge Design and Construction J. A. L. Waddell	The Activated Sludge Treatment Process T. Chalkley Hatton	Highway Transport Problems Maxwell Halsey

1:30 P.M.

Teaching Reinforced Concrete W. K. Hatt	Sanitary Biology Gordon M. Fair	Fundamentals of City Planning George B. Ford

7:30 P.M. Lecture .....(Speaker to be announced)

SATURDAY, JULY 19

8:45 A.M. Applying the Test of Economy to Structural Design
C. W. Mayers

10:15 A.M. Aesthetics of Structural Design .....Charles S. Whitney

MONDAY, JULY 21

8:45 A.M. Divisional Meetings

Structural Division	*Sanitary and Hydraulic Division*	*Highway and Railway Division*
Suspension Bridge Design D. B. Steinman	Hydro-Electric Practice W. P. Creager	Traffic Control Maxwell Halsey
10:15 A.M. Design and Construction of Welded Steel Structures F. P. McKibben	Hydraulic Research C. M. Allen	Economics of Railway Operation J. E. Slater

1:30 P.M. The Teaching of Metallography .....C. H. Mathewson

TUESDAY, JULY 22

8:45 A.M. Divisional Meetings

Structural Division	*Sanitary and Hydraulic Division*	*Highway and Railway Division*
The Hudson River Bridge O. H. Ammann	New York City Water Supply System; and Logic of Engineering Diagnosis Thaddeus Merriman	The Westchester County Parkway System A. G. Hayden

10:15 A.M. Lecture .....(Speaker and subject to be announced)
1:30 P.M. Reports of Committees
6:00 P.M. Subscription Dinner

WEDNESDAY, JULY 23

Inspection of engineering works in New York City:
Structural Division—Hudson River Bridge
Sanitary Division—Catskill Aqueduct Works—City Tunnel
Highway Division—Westchester County Parkways

5:00 P.M. Adjournment.

Session on Drawing and Descriptive Geometry

The session on engineering drawing and descriptive geometry will be held at the Carnegie Institute of Technology, Pittsburgh, from June 12 to June 21, inclusive. These dates were chosen as a result of an extensive canvass of the preferences of teachers of drawing. The closing date of the session is such that members who wish to attend the annual convention of the Society at Montreal can go directly from Pittsburgh to Montreal and arrive in time for the meeting.

The members of the summer school group will be housed in dormitories of the Institute and meals will be provided at one of the dining halls. The cost of attendance will be limited to a registration fee of $10 and to the cost of room and meals, which will not exceed $35 for the entire period of the session. The registration will be limited to 100. Seventy-six applications have been received thus far.

The program of the session, which has been arranged in cooperation with the executive committee of the drawing division of the Society, will deal with the objectives of courses in drawing and descriptive geometry, with content of courses, methods of instruction, the use of the several types of classroom and drawing room exercises, and with the organization and administration of engineering drawing departments. A portion of the program will be devoted to demonstrations of teaching methods and another portion will be carried out through the activities of committees of members who will prepare reports on a number of important problems that confront teachers of drawing. A special feature of the session will be visits of inspection to a number of industrial drafting rooms and manufacturing plants in the Pittsburgh district, which provides an unusually wide variety of examples of different types of industries. Visits will also be made to the art galleries of the Carnegie Museum and to other points of interest in and around Pittsburgh.

The staff of the drawing session will comprise teachers of drawing and teachers and executives from other divisions of engineering education, also engineers in practice. The complete list of staff members and program of the session follows.

STAFF

LOCAL DIRECTOR OF THE SESSION: William E. Mott, Director, College of Engineering, Carnegie Institute of Technology
SECRETARY: Harry M. McCully, Professor of Drawing and Descriptive Geometry, Carnegie Institute of Technology.
CHAIRMAN OF THE TEACHING STAFF: Thomas E. French, Professor of Engineering Drawing, The Ohio State University

Franklin DeR. Furman, Dean, Stevens Institute of Technology
H. W. Harrold, Registered Architect
Frederic G. Higbee, Professor of Descriptive Geometry and Drawing, State University of Iowa
Randolph P. Hoelscher, Associate Professor of General Engineering Drawing, University of Illinois
George J. Hood, Professor of Engineering Drawing, University of Kansas
Harvey H. Jordan, Professor of General Engineering Drawing, University of Illinois
A. E. Lofberg, Section Engineer, Westinghouse Electric & Manufacturing Co., East Pittsburgh
Clair V. Mann, Professor of Engineering Drawing and Descriptive Geometry, Missouri School of Mines
Henry W. Miller, Professor of Descriptive Geometry, Mechanism and Drawing, University of Michigan
P. J. Reich, Division Engineer, American Bridge Company, Pittsburgh
Robert L. Sackett, Dean, School of Engineering, Pennsylvania State College
Charles H. Schumann, Jr., Associate Professor of Drawing, Columbia University
William G. Smith, Associate Professor of Engineering Drawing, Northwestern University
Carl L. Svensen, Professor of Engineering Drawing, Texas Technological College
William D. Turnbull, Junior Dean and Secretary, College of Engineering, Ohio State University
Frank M. Warner, Assistant Professor of Engineering, University of Washington
William E. Wickenden, President, Case School of Applied Science

PROGRAM

THURSDAY, JUNE 12

9:00 A.M. Registration
11:00 A.M. Address of Welcome
John L. Porter, Chairman, Trustees Committee on the Carnegie Institute of Technology
Purpose of the Summer School ..... Harry P. Hammond
Outline of the Program ..... William E. Mott
Appointment of Committees
Announcements
1:30 P.M. The Orientation of Freshmen to Engineering—Robert L. Sackett
2:30 P.M. Relationship of Engineering Drawing Courses to the Engineering Curriculum ..... Franklin DeR. Furman
3:30 P.M. Objectives of courses in Drawing and Descriptive Geometry ..... Thomas E. French
Evening: Smoker

FRIDAY, JUNE 13

8:30 A.M. Standards for Drawing and Drafting Room Practice ..... Franklin DeR. Furman
9:15 A.M. The Content of an Engineering Drawing Course. Harry M. McCully
Discussion
1:30 P.M. The Content of a Descriptive Geometry Course.. William G. Smith
Discussion

SATURDAY, JUNE 14

8:30 A.M. Sectioning Students on the Basis of Ability... Henry W. Miller
Discussion
10:15 A.M. Aptitude Tests and their Use in Sectioning Students ..... Clair V. Mann
Discussion
Afternoon: Recreation

MONDAY, JUNE 16

8:30 A.M. The Use of the Recitation in Teaching Drawing ..... Randolph P. Hoelscher
Discussion
10:15 A.M. The Problem Question: Source, Presentation, Laboratory Methods ..... Carl L. Svensen
Discussion
1:30 P.M. Engineering College Preparation for the Industrial Drafting Room ..... A. E. Lofberg
3:30 P.M. Visit to the Koppers Company

TUESDAY, JUNE 17

8:30 A.M. A Survey of the Methods of Teaching Descriptive Geometry ..... George J. Hood
Discussion
The Use of the Recitation Period in Descriptive Geometry ..... Carl H. Schumann, Jr.
10:30 A.M. The Use of the Laboratory Period in Descriptive Geometry ..... William G. Smith
Discussion
1:30 P.M. Engineering College Preparation for the Industrial Drafting Room ..... P. J. Reich
Discussion
3:00 P.M. Visit to McClintic-Marshall Company
Evening: Visit to Alleghany Observatory

WEDNESDAY, JUNE 18

8:30 A.M. Demonstration Teaching:
1. A Class in Engineering Drawing ..... Thomas E. French
2. A Class in Freehand Lettering ..... William D. Turnbull
10:15 A.M. Demonstration Teaching:
3. A Class in Descriptive Geometry ..... Harry M. McCully
4. A Class in Descriptive Geometry ..... George J. Hood
5. A Class in Descriptive Geometry ..... Frederic G. Higbee
1:30 P.M. Visit to Westinghouse Electric & Manufacturing Company

THURSDAY, JUNE 19

8:30 A.M.	Organization and Administration of an Engineering Drawing Department .....Harvey H. Jordan Discussion
10:15 A.M.	The Responsibility of the Teacher .....William E. Wickenden
1:30 P.M.	The Development of a Course in Engineering Drawing .....Frank M. Warner Discussion
Evening:	Visit to Carnegie Museum

FRIDAY, JUNE 20

8:30 A.M.	History of the Development of Graphical Representation .....Frederic G. Higbee
9:30 A.M.	Report of Committee No. 1—Aims and Purposes of Engineering Drawing Courses
10:15 A.M.	Drafting Room Design: Equipment and Appliances. H. W. Harrold
1:30 P.M.	Report of Committee No. 2—Methods of Teaching Engineering Drawing Report of Committee No. 3—Aims and Purposes of Descriptive Geometry Courses Report of Committee No. 4—Methods of Teaching Descriptive Geometry
Evening:	Demonstrations: Manufacturing and Printing Processes used with Drawing Papers

SATURDAY, JUNE 21

8:30 A.M.	Report of Committee No. 5—Coordination of Drawing and Descriptive Geometry Courses with other Courses Report of Committee No. 6—Examinations and Tests of Achievement Report of Committee No. 7—Drafting Instruments and Appliances Report of Committee No. 8—Pre-College Training in Engineering Drawing
10:15 A.M.	Examinations and Tests of Achievement .....Clair V. Mann
1:30 P.M.	Examinations and Tests of Achievement .....Clair V. Mann
Evening:	Subscription Dinner. Gardner L. Anthony, guest of honor (An exhibition of drawing instruments and of drawing room appliances will be on display throughout the period of the session.)

Applications to attend both the drawing and descriptive geometry session and the civil engineering session of the Summer School should be addressed to H. P. Hammond, Director of Summer Schools, Society for the Promotion of Engineering Education, 99 Livingston Street, Brooklyn, N. Y.

REPORT OF THE CONFERENCE ON ELECTRICAL ENGINEERING, JUNE 20, 1929, AT ANNUAL MEETING OF THE SOCIETY, OHIO STATE UNIVERSITY

THE PLACE OF ILLUMINATION ENGINEERING AND PHOTOMETRY IN THE ELECTRICAL ENGINEERING CURRICULUM

By H. H. HIGBIE *

The curriculum in electrical engineering at the University of Michigan has long contained a two-hour course in illumination and photometry required of all candidates for degree in electrical engineering. The course has improved naturally with the experience of years but the requirement has not been augmented as the expected opportunities should have demanded. Expansion in the science and art of lighting, and of our resources of personnel and laboratory equipment, have permitted us to offer four elective courses of instruction for students wishing to specialize in this field. Illumination engineering, either as a specialization within the field of electrical engineering or as a distinct profession, has not yet attained to the place of recognized importance which we who teach it hoped for and still expect, but it amply deserves a definite allottment of time in every electrical and engineering curriculum.

Trustworthy figures show that in the United States alone during the year 1928 the total expenditure by the public for lighting by means of the incandescent lamp was, in round figures, six hundred million dollars. The greater part of the revenue of most generating stations is derived yet from their lighting loads. Notwithstanding the progress made in popularizing electrical devices for purposes other than lighting, it is true that opportunities for improvements in light generation and utilization are not excelled in any other field, and that the effects of such possible improvements upon the elec-

* Professor of Electrical Engineering, University of Michigan.

trical industry and profession should be most profound and far-reaching.

The need of brains, expert knowledge and technical training is at least as great in lighting work as in any other field. The amount and diversity of knowledge required in a lighting expert is certainly more than enough to demand a specialized curriculum in illumination engineering in any college that may hope to give adequate training for this field. Such a curriculum should provide for special fundamental courses in psychology, physiology and hygiene, fine arts and architecture, besides more than the usual amount of work in physics of light, in substitution for some of the usual content of an electrical engineering curriculum. Proper sequence in this work would perhaps require the specialized training to begin with the third year of college and extend through a fifth year. Those who are now lighting experts and have had to acquire such knowledge on their own initiative outside of college, or who have felt the lack of it, will I am sure frankly admit the need of it in any curriculum intended to prepare college students to enter effectively into this great field of service.

But regardless of how desirable it may be to make the educational resources of a university as complete and comprehensive as possible, it is useless to organize special courses of instruction, and it is impracticable to allocate the time of teachers to such specializations, unless a respectable proportion of students elect them. Students will not elect such courses and curricula, and teachers cannot conscientiously try to interest students in them, unless opportunities for satisfactory employment of such training are provided for the students after their graduation from college. We observe, however, that so far, even those employers of engineering graduates whose business is specialized in lighting, do not particularly encourage the development in colleges of means to interest or to train any considerable number of the students in lighting science and art. All of them lay down as the first prerequisite for employment that a student should have the personal qualifications of a potentially successful sales-

man. If he has such qualifications, which do not particularly involve engineering training and in many cases can be found in men with no college training at all, the employer will undertake to make a "lighting expert" of him by a few weeks or months of intensive training in a "lighting institute" or commercial school which, though established originally to propagandize better lighting and thereby increase the demand for lighting products, has become an "educational" institution for rapidly putting a "lighting expert" veneer over successful salesmen of whatever antecedents. Self-respecting and ambitious college students cannot be expected to aspire to or strive for connections in which there is no premium upon qualifications they have spent time, effort and money to acquire.

It is beside the purpose of this paper to discuss fully what may be the causes and remedies for such a lack of respect and interest among college students for lighting as a life work, and such absence of incentive for them to enter a field potentially so important. Whatever may be the distribution of responsibility for the existence of such a state of affairs, the facts that must be faced do not encourage faculties to institute departments or courses of instruction adequate to meet the future demands that should logically be expected for properly trained lighting experts. Where faculties have done so, they have been moved not so much by a considerable demand for graduates in this special field, nor even by a demand that is steady though small, but rather by foresight and faith greater, apparently, than possessed by the employers.

The University of Michigan is one of the few institutions which have long sought to qualify themselves especially to fill this need that reasonably should exist. We hope it is not an indication of our incompetence that, during the last twenty years, we have placed in the lighting field each year from none to four or five graduates, averaging about two; and that this demand has been very erratic, it having been impossible in some years to place even one graduate specifically in lighting work. During this period our total number of graduates in electrical engineering has ranged from forty to one hun-

dred or more per year, averaging perhaps sixty; so that the lighting field claimed always less than four per cent. of our product, averaging perhaps two or three per cent. However much a student may have been interested in lighting and however conscientiously and thoroughly he may have prepared himself to deal with the complex and important problems involved, he can hardly hope to be given a chance at these problems unless he happens to be prospectively a personable salesman of "lighting service" or of lighting equipment. Considering this, we can understand the obvious reluctance of colleges to prepare themselves for training students in this field. In the general field of electrical engineering and in its other departments of specialization, a well-informed, thoughtful and energetic graduate is sure to find his services in demand somewhere. Not all people are born to be "mixers," and as long as the lighting business demands and will accept only a rare combination of specialized scientific interest, æsthetic sensibility, far-sighted ambition and salesman-like personality, it may expect to have little preparation made by colleges for supplying its future needs of personnel.

It is significant that illumination engineering, or lighting, as a distinct vocation is not yet sufficiently recognized to be worthy of inclusion as a separate classification in a list of forty-two distinct curricula mentioned in a "Summary of Enrollments in Engineering Schools and Colleges of the United States." This summary, covering one hundred forty-eight schools, is published in the June, 1928, issue of the Journal of Engineering Education. It includes specifically such specializations as "cotton classing and marketing" which attracted and presumably absorbed 54 students, "sugar engineering" 44, "flour mill engineering" 9, "geodesy and surveying" 8, in the year 1927–28 when electrical engineering in general enrolled 20,210 students out of a grand total of 65,520 for the whole field of engineering. It seems to me that this stands out as an indictment of the methods and ideals of the lighting industry and business, when we consider that the need and existence of a lighting profession was recognized formally as long ago as 1906 by the formation of an Illuminating Engi-

neering Society having as a purpose avowed in its constitution "the advancement of the theory and practice of illuminating engineering and the dissemination of knowledge relating thereto."

Several years ago, as president of that Society, I created a Committee on Education with a sub-committee charged to investigate the needs for lighting education in colleges. The report was made by A. A. Brainerd and Lewis Fussell, both of whom had long served as professors of electrical engineering in colleges but were at that time engaged in work with electricity supply companies. I quote now almost in full the conclusions of that committee.

"This study shows that in many cases, if not most cases, the lighting engineers have received supplementary training at the various lighting schools conducted by the lamp companies in addition to their college work. It is certainly a matter of doubt whether any great percentage of lighting engineers received their lighting training in college. There is no question but that the lamp works schools are wonderfully efficient, but the time available in these training schools is so short that it is ridiculous to expect them to take the place of a thorough grounding in fundamentals in a special course at college.

"It is apparent that if all present requests could be filled a total of 842 college graduates would be required to maintain the central station lighting service throughout the country. Allowing for those who leave work for various reasons, the average period spent by a college graduate in lighting work might be estimated at around twenty years. If this is true, the yearly demand for college-trained lighting engineers would certainly not be over forty-two. If we add to this the demands of the lamp companies and similar agencies, the annual demand would certainly not be over sixty. These could expect $100 to $150 per month to start and would probably rise to $2,000 or $2,500 per year within a few years. Under the present day conditions, a man could hardly be classed as more than making a living and certainly not as an astounding success if he does not eventually earn $5,000 per year. Yet present indications are that there is probably not more than one lighting man of this class to a population of 2,000,000 and future needs would not demand the service of more than one man of this class to a population of 1,000,000. In other words, on the basis of the present number of people who have electric service available, there certainly are not over one hundred good jobs in central station lighting in the whole United States.

"The general concensus of opinion among lighting service officials is

that college men are essential to handle the engineering work, but that straight selling of lighting can be carried on by a much lower grade of men by the use of standardized plans and methods. There is unquestionably a great work to be done which must be handled by college men especially trained for the job, but it would be foolish to attempt to induce the colleges as a whole to put on special courses in illuminating engineering. A more practical plan would be to select a few well-equipped colleges and concentrate the major portion of our effort in these institutions. Other colleges should install one or possibly two elective courses in illumination in order to create and maintain a nation-wide interest in better lighting. Central stations should be systematically encouraged to conduct lighting classes among their own employees. High school physics courses should have illumination included as a matter of health and general knowledge. But the main intensive effort which should be the mainspring of all these other activities should be placed in one or two specially equipped colleges. Such institutions could then be made the centers of illumination research and should do much to further the rapid advance of the lighting art.''

Imagine the automobile business, or the radio business, or the motion picture business developing to its present magnitude, under the impulse of brains and effort of only one hundred men who could look forward to five thousand dollars per year or more! And yet those things are obviously luxuries, while light is generally recognized as a necessity which profits the consumer of it as well as the producer.

It is interesting to note how these views are reflected by reports of the Board of Investigation and Coordination of this Society. Out of 271 members of the American Institute of Electrical Engineers whose replies to a questionnaire were summarized, only 6.6 per cent. believed that lighting is of sufficient importance to warrant provision of a distinct complete curriculum specializing in Illumination; preference was given to telegraphy 21.8 per cent., electrochemical 18.4 per cent., power plant 16.6 per cent., radio 16.2 per cent., transmission 12.3 per cent., electrical machine design 11.0 per cent., hydroelectric 9.2 per cent., industrial electrical engineering 7.7 per cent., and electric railways 7.4 per cent.

I personally believe it is unreasonable for us to arrange our curriculum so that a student may be graduated from college as an electrical engineer without any idea as to what constitutes

proper lighting for his desk, his shop, his office or his home, and yet he is forced to study about such matters as hydro-electric plants or electric railways with which few will ever be concerned. On the other hand, as preparation for life and business in general, I am sure that the study of lighting with its complex interrelation of human and physical elements is at least as good as the study of communication, or electrochemistry, or electrical machine design.

Reports in the September and December, 1926 issues of the JOURNAL OF ENGINEERING EDUCATION indicate that a large majority of both practicing engineers and teachers believe engineering colleges should have a number of curricula moderately or slightly but not sharply differentiated from each other. The extent to which specialization or subdivision of curricula should be carried (such as sanitary or structural engineering within the major field of civil engineering, or illumination within the major field of electrical engineering), and the provision which should be made for preparing students to follow particular lines of engineering work, was covered by 534 replies to a questionnaire, representing 115 engineering faculties. To the question whether or not engineering colleges should offer specialized undergraduate curricula in subdivisions of the major fields of engineering, slightly more than half the teachers who replied indicated that they favor the provision of such curricula, but considerably more than half expressed the belief that such provision should be made in a few institutions only. There was nearly unanimous agreement in opinion that the primary purpose of instruction in "specialized" engineering subjects should be to teach fundamental principles and methods rather than to train for particular kinds of work. Opinions of the practicing engineers are in agreement with these views. The report concludes its discussion of this subject as follows: "If any one statement could adequately summarize the great number and diversity of opinions expressed it would probably be that specialization has a legitimate and necessary place in engineering education but that it should be confined to post-graduate courses and to those institutions which are qualified

to offer the work as genuine professional study of high grade."

From all the foregoing considerations we may conclude that, though lighting with its cognate subjects deserves more attention in universities than it is generally receiving, either in courses of instruction or in research work, developments will be slow until lighting business changes its point of view with respect to the technician, whom it needs perhaps more than it realizes or is willing to admit; that there is already an opportunity for a few colleges to specialize in this field, where they have or can develop unusual laboratory facilities and personnel; and that the subject of lighting deserves some attention in all colleges of engineering in undergraduate curricula not only of electrical engineering but of other major departments as well, such as industrial and architectural engineering. It is particularly of the last subject that I wish now to deal; and in a way to emphasize basic principles rather than current educational practices.

Let us consider next the character of the first course, which in most cases will be the only course offered in lighting. There is often a temptation to make it quite practical; students are supposed to prefer a practical sort of course which gives an impression of immediate utility and value. But this motif in engineering education is being progressively discredited.

Our first course treats of such matters as light concepts and units; quantitative relations between lumens, candle-power, foot-candles and lamberts; calculations of light output and efficiency of sources, using not only various point-by-point methods of mechanical integration for sources whose candle power distribution is not conveniently representable by a mathematical function, but also the method of the calculus upon idealized sources whose candle-power distribution can be so represented; calculation of distribution of direct illumination from candle-power distribution of point, line and surface sources, both practical sources and those that have been idealized to permit application of the calculus for finding maximum and minimum illumination and gradients of illumination; theory of light in an enclosure, and such of its applications as integrating spheres, reflectometers, enclosing

glass globes, and design of lighting in cases where indirect component is large and utilization coefficient unknown. Attention is also given to the physics of light production, and the operating characteristics of practical light sources.

We think it should be a prime object of the first course to develop such understanding of and familiarity with the concepts, nomenclature and fundamental quantitative relations of this new engineering science of light that our graduates who are likely to have to deal with such matters shall know where to find quickly the latest and best information and shall know how to use it without delay and uncertainty after they find it. Experience shows that it is difficult even for some expert electrical engineers who received their college training before the science of lighting was developed, to acquire precise ideas and habits in the use of it, witness errors that have frequently appeared even in textbooks and papers written by such engineers. We know from testimony of students that a first course in illumination and photometry, with content and method such as have been described, can be of great assistance in clarifying their ideas and strengthening their memories about electric and magnetic fields; the mathematical relations involved there are quite similar to those of light fields, and the mind seems better able to acquire a realizing physical sense of light than of either electric or magnetic quantities and relations. The course thus readily lends itself to the achievement of objectives sanctioned by both practicing engineers and teachers of engineering for instruction in special subjects; in both these groups of critics replying to the questionnaire that has previously been mentioned, about 94 per cent. believe that such courses should serve primarily as means of teaching fundamental principles, and only 6 per cent. hold that they should serve to train students for particular fields of work. As our own course is conducted, the calculus on which the students spend so much time during the first two years is probably used more consistently than in most other electrical courses of the third and fourth years, and not merely as mathematical exercise but because the calculus is obviously essential to the solution of the lighting problems attempted.

Our first course in lighting consists of lectures, problems and laboratory work. The lectures are quite essential to presentation of the subject as we wish to give it. The problems are of an obviously practical nature but with a theoretical aspect, and many of them are based upon data and methods published in the *Transactions of the Illuminating Engineering Society* and the current literature of lighting. The course gives two semester-hours credit for two hours per week in lecture room and six three-hour laboratory periods distributed over the semester. We use a text book, but procure for each student a collection of selected bulletins of lamp and reflector manufacturers, not only to keep the text material up to date but also to develop a habit of collecting such material. Our laboratory experiments are as far as possible in the nature of projects; such as, to show the influence of dirt on glassware, the experimental checking of theoretical laws for distribution of illumination from point, line and surface sources, or the survey of a lighting installation to discover defects and their causes. For this reason the reports that are required, having an interesting basis, are not as irksome to the students as the formal and perfunctory reports usually required in electrical laboratories; many times they have been made a medium of helpful cooperation with the Department of English, which has undertaken to correct the form and diction of the reports.

Toward the end of our course the student is required to report upon a lighting installation of which he has considerable experiential knowledge, pointing out its faults and specifying remedies. Many students have been moved by interest to do much finer work than it would be practicable to require in this exercise, actually carrying out their constructive suggestions in some cases, and frequently making photometric measurements and photographs before and after the alterations in the lighting system. Bad lighting is so common that the student can be led to notice and analyze the faults all around him as soon as he has become acquainted with the fundamental principles. This not only develops a lighting consciousness that is likely to be valuable always, but gives the student very often the first real experience in applying

his theoretical and engineering instruction. Long before the young engineer is permitted to take responsibility for decision in other electrical matters, he is likely to find his opportunity to do some job in lighting perhaps in his home or office; in fact, several of our students have received and fulfilled contracts to install or rebuild lighting systems. Not only this, but the collective results of the work of a class have often been made the basis of engineering reports to the Buildings and Grounds Department of the University of Michigan; as, in checking the results of janitors' neglect of the task of cleaning glassware, or finding the causes when lighting in University buildings has become unsatisfactory.

With this first course as basis and prerequisite, we have developed already several other courses for those who wish to specialize to some extent in lighting, perhaps with a view to making this field a lifework, perhaps merely as a passing interest. We have a course in Study of Design of Interior Illumination, which is mainly devoted to a critical comparison and evaluation of methods used and useful for the design of lighting. We have a course in Natural Lighting of Buildings, intended especially for architects, in which methods are given for comparing the effects of various changes of fenestration upon the amount and distribution of daylight in the building. We have also a seminar in lighting, in which each student chooses a subject with approval of the instructor, and studies exhaustively the literature of that subject, making oral report for perhaps ten or fifteen minutes to the assembled class each week or two, and a written report to the instructor when the study has been completed. We have a brief course of lectures on Building Illumination without prerequisites, intended for architects and students of public health. Years ago we had a course in Street Lighting which was abandoned as being too highly specialized in a field where there was too little demand for analytical knowledge; with advances in the science and art, it may be desirable to revive this course. If it ever proves to be worth while, we may add courses in Light Projection Engineering, in Electrical Distribution and Control for Lighting, in Physiology and Psychology of Lighting,

and other subjects in which the science has been particularly well developed and a considerable body of knowledge has become available.

It is quite apropo now to consider how much of this work, if any, should be placed among the definite hard-and-fast requirements for the first degree in electrical engineering. On this point I am at variance with the mass opinion of those who answered the questionnaire to which reference has previously been made. Only one-third of those who answered believed that the study of illumination is of such importance as to warrant inclusion of it in the training of all electrical engineers. I believe lighting is one of those essential matters that all electrical engineers will be expected to know. The public has come to recognize communication, particularly telephony, as a field for specialists, and does not expect every electrical engineer to have intimate knowledge of it; but the public, itself somewhat conversant with matters of lighting on account of the educational propaganda of concerns selling lighting equipment, certainly expects everybody who calls himself a professional electrical engineer to be almost as familiar with the principles of correct lighting as with motors and generators and power plants. Even after the necessity for lighting specialists shall have become sufficiently recognized to cause the establishment of special curricula for them, it should still be necessary to include at least one two-hour course on fundamentals of lighting in every electrical engineering curriculum, in order that electrical engineering graduates shall be merely intelligent with regard to the commonest aspects of their work. It should also be recognized as necessary to have a required course on lighting in the curricula of architectural engineering and of industrial engineering; in the former it is just as important as heating and ventilation or sanitation, which are usually required, and in the latter it is just as important as other production methods and factory hygiene. Some instruction in lighting should also be given to all students of household science and of interior decoration.

If schools of engineering take the initiative and make it their practice to send out graduates who are at least some-

what conscious that lighting is a science and an art worthy of serious study, perhaps they may expect thereby to hasten the day when industry and business shall require special training for those who deal with lighting problems and with the development of the business. As colleges of engineering were conceived and established long before the necessity of college training for engineers was conceded by business and industry, and as engineering colleges have grown and prospered in spite of this initial antagonism or lack of appreciation, perhaps we should presume to take initiative in opening up this new field for college-trained men and women, and help them to create the demand for their own services.

LECTURE ROOM DEMONSTRATIONS OF CERTAIN PHENOMENA IN COMMUNICATION ENGINEERING

By W. L. EVERITT *

Educators and employers are in almost universal agreement that the important function of engineering education is to impart as thorough a knowledge of fundamentals as possible and to develop reasoning powers which can apply these fundamentals. At the same time it is realized that the students interest is stimulated, and his appreciation of the value of these fundamentals is increased, if he is shown applications to engineering practice. It is in this respect that engineering education differs from more general scientific courses.

In electrical engineering curriculum emphasis has often been placed on those fundamentals which are of primary importance in the generation and utilization of power, and other phenomena equally as fundamental have often been neglected as of no importance. In most courses at present given in Communication Engineering, the emphasis is not placed on applications, but rather on those physical principles which find their fullest fruition and are best illustrated in the Communication field. Such courses should not be labelled "Application Courses."

It has been the history of all branches of knowledge that after a period of growth there is a tendency to subdivide under different headings, as a tree divides into branches. At first it is easy to determine which facts belong to one branch and which to the other, and the separation seems to increase. But soon it is found that the result of research in one field has important applications in the other, and there begins to be an interleaving of the branches of the tree so that it is difficult to see to which branch an individual twig belongs.

* Associate Professor of Electrical Engineering, Ohio State University, in charge of Communication Courses.

In the same way many phenomena which have been largely developed in Communication Engineering, and might be taught under a course by that name, are becoming of increasing importance to the power engineer, so that it may safely be said that the training of any electrical engineer would be as incomplete without attention to these fundamentals as though other basic subjects were omitted.

To be specific four fundamental groups of phenomena which might properly be taught in a course on Communication Engineering, and are so grouped at the Ohio State University may be mentioned. They are:

1. Wave motion on transmission lines and in free space.
2. The interaction of currents of different frequencies in linear and non linear networks.
3. The use of Vacuum Tubes.
4. The behavior of networks under impressed voltages which vary over, or consist of, bands of frequencies.

Wave motion on transmission lines show its most pronounced effects on telephone lines and radio antennas, because the higher frequencies used reduce the wave length so that several waves may exist on an actual line. Furthermore, more control is usually possible over the terminating impedances, and at the same time, instead of operating at a single frequency, a whole band of frequencies is frequently utilized. A subject of increasing importance to power engineers is the action of transient disturbances on transmission lines. Many of these effects can be most easily predicted from a knowledge of the response over a wide band of frequencies. This is particularly true where terminating networks are complex, a condition met with even where there is only a single transformer; since the various frequency components of the transient are influenced to different degrees by distributed capacity, eddy currents, etc. The engineer who has been trained to analyze circuits under varying frequency will be better equipped to attack many problems in all branches of electrical engineering.

Vacuum tubes, and electronic flow in general, have many

applications in all branches of science. Examples of their use are the study of noise in mechanical machines, the detection of flaws in rails, automatic train control, stethoscopes, as well as the more common application to the production, amplifications, rectification and detection of alternating currents.

The use of laboratory experiments is a well established method of scientific instruction. Many experiments of educational value are not adapted to use in the regular laboratory classes, but can be profitably introduced in the classroom to supplement the more theoretical instruction. It is the purpose of this paper to describe some of the lecture demonstrations which have been found of instructional value in emphasizing the four groups of phenomena mentioned.

The first of these is a model which shows by synthesis the wave relations on a transmission line.

The equations ordinarily used in the solution of long electrical lines, vibrating strings, or organ pipes do not give a very clear physical picture of the relations involved. This mechanical model portrays these physical relations.

A disturbance impressed on an electrical line having distributed constants of inductance and capacitance has a finite velocity of propagation. Furthermore, when the disturbance reaches the far end of the line, part of the energy in the disturbance will be reflected, unless the load impedance is equal in magnitude and phase to the surge impedance of the line and therefore can receive the current and voltage in the same ratio as existed while they were being propagated along the line.

As a result of this, there will exist on the line, in the general case, two waves traveling with equal velocities in opposite directions, and being attenuated or dissipated as they pass along the line, due to losses in the line. This conception of two waves is usually more important in the electrical than the mechanical case because of the better control of terminal impedances, by which the amount of reflection can also be controlled.

A wave passing in the positive direction along the x axis, can be represented by the equation:

$$y = Ae^{(-\alpha-i\beta)x},$$

while a wave traveling in the negative direction along the x axis will be represented by a similar equation:

$$y = Be^{(+\alpha+j\beta)x}.$$

In these equations, the real exponent denotes attenuation, or the loss of a certain proportion of the energy, while the imaginary exponent shows a shift in phase along the line due to the finite velocity of propagation, which makes corresponding events occur at later instants as the wave progresses.

The complete solution of voltage or current on an electrical line can therefore be represented by the equation:

$$\bar{y} = \bar{A}e^{-\gamma x} + \bar{B}e^{+\gamma x},$$

in which the terms A, B, and γ are complex functions of the constants of the line, load, and generator. In the electrical case, it is customary to reassemble the exponential equation into one involving hyperbolic functions, to obtain the familiar transmission line equations of which the following is an example:

$$E_1 = E_2 \cosh \gamma x + I_2 Z_0 \sinh \gamma x.$$

While the hyperbolic functions are ordinarily considered more simple to evaluate, it is at this point that one is apt to lose sight of the physical idea of an initial and a reflected wave. In mechanical vibrations it is more customary to show similar relations by complex circular functions. The phase angle between the two waves varies along the line, and therefore when the summation is performed, maxima where the two waves are in phase, and minima where the waves are 180° out of phase, will be obtained. The presence of maxima and minima are generally spoken of as standing waves, and such waves can be detected with a voltmeter on an electrical line which reads effective values, while a single traveling wave cannot be detected by such means.

Mechanical Model of Transmission Line Relations

In order to show the phase relations from point to point, and their resulting summations, the model shown in Fig. 1

was constructed. A brass band has its upper edge cut in the form of a sine wave. Ten cycles cover the total length of ten feet. This brass band was passed around two cylinders which rotate on vertical axles at the two ends of the model. At intervals of one and one-half inches verical slots are cut in two horizontal grooved strips, one on the front and one on

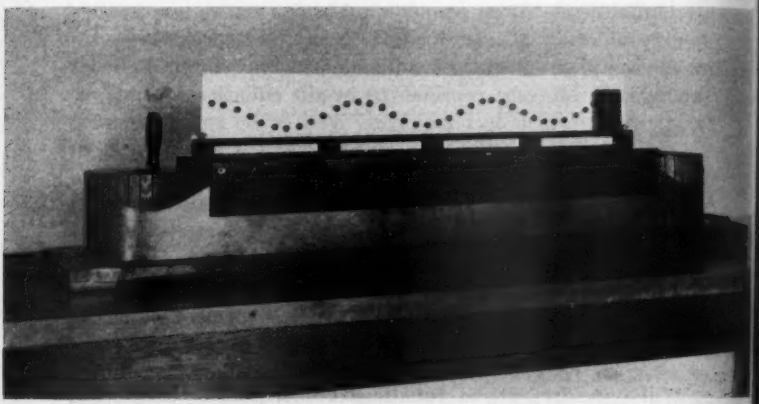


FIG. 1.

the back part of the band. In these vertical slots rest brass rods. These rods are constrained by the slots from moving horizontally, but their vertical motion at each end is determined by the sinusoidal cut on the brass band upon which they rest. When a cylinder is rotated, the ends of the rods nearest the observer show a traveling wave moving from left to right, while the ends away from the observer show the motion of the reflected wave moving from right to left.

At the center of each rod, and pivoted to it, is attached a vertical rod. The movement of the center of the rod is always half the sum of the movements of the two ends of the rod. Since the one-half is a constant factor, the movement of the attached vertical rod shows the sum at that point of the two waves. Attached to the top of these vertical rods are wooden

beads. These vertical rods are constrained to move only in a vertical direction, by means of a third horizontal strip with drilled holes, through which the rods pass. This construction is shown by the end view of Fig. 2, where the cylinder has been removed.

When the guide of the vertical rods is half way between the front and back of the brass band, and parallel to it, the reflected wave is of the same magnitude as the initial wave,

FIG. 2.

and there is no attenuation of either wave. The standing wave is shown by the beads having nodal points, with no motion, at intervals of one-half wave length. This condition is approximated in radio antenna where the attenuation per wave length is small. A similar condition exists in the vibration of strings and organ pipes.

An examination of the motion of the rods gives a very accurate picture of the phase relations between the two waves at different points along the line, and therein lies one of its

most important advantages. At the nodal points, the two ends of the rod will be out of phase, one end moving up as the other moves down, giving a rocking motion about the center, and hence imparting no motion to the bead. On the other hand, at the anti-nodal or maximum points, the two ends of the rod move together showing that here the two waves are in phase.

In order to make the model more versatile, the guide of the vertical rods rests at each end on a slotted brass strip, so that it can be moved relative to the brass band. Its position when once set is held rigid by means of thumb screws. If the guide is moved so that it is nearer the front side of the brass band, but parallel to it, the front edge will have more effect on the beads than the back, and therefore the condition where the reflected wave is weaker than the initial wave is simulated. Since the guide is parallel, there is still no attenuation. Due to the weaker reflected wave the nodal points will not have zero motion, the movement will be finite but a minimum with respect to the other points. This condition corresponds to a termination on the line where there is some absorption of energy, and therefore the load has a resistance component.

If the guide is placed at an angle to the brass strip, the relative magnitude of the initial and reflected waves will change along the line, and therefore correspond to the case where attenuation or absorption in transmission exists. The initial wave will be reduced when passing in the positive x direction, while the reflected wave will be reduced while passing in the opposite direction. The nodal points will therefore have the least motion near the receiving end, and will gradually increase as the sending end is approached. While the attenuation cannot be made exponential by this model, the other relations are shown very well.

In order to show on the beads the motion when all the energy is absorbed at the receiving end and there is no reflected wave, a horizontal stop is provided on the back of the model which can lift the rods clear of the brass band on the back. A single traveling wave with or without attenuation can then be shown.

The reactive component and magnitude of the load determines the phase shift during reflection. In order to show this action it is only necessary to change the bead acting as the end of the line. This can most readily be done by covering one or more of the end beads by a small black screen provided, and shown at the right of Fig. 1. By covering one quarter wave length the difference between an open and short termination can be shown.

Aside from its application to the transmission line relations, this model also is an effective way of showing the need for vector addition of sine waves out of phase in elementary theory, for a variety of phase angles between two vectors adding together are available at the different points along the line.

Electrical Model of Transmission Line Relations

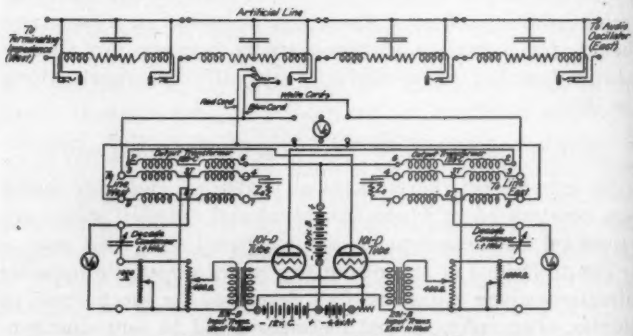
To supplement the mechanical model, an electrical model was constructed in which the initial and reflected waves are separated for measurement, and compared with their sum.

The technique of separating two waves passing in opposite directions along a line was first developed for the purpose of duplex telegraphy, so that messages could be sent simultaneously in opposite directions. The technique was further refined for application to telephone repeaters, as it is necessary to separate the two waves in order that a repeater may be made to amplify in both directions without howling. The method used here is that of the telephone repeater, with some simplification since no gain is needed. Incidentally therefore, the model illustrates this important principle in communication practice.

The wiring diagram is shown in Fig. 3. The gain control is adjusted so that there is no gain or loss in passing through the apparatus. The impedances must be carefully adjusted so that there is no reflection at the repeater. The separation of the two waves is obtained by a bridge balance, and the reader is referred to the extensive literature on telephone repeaters for further information upon the details. Voltmeter A will read the voltage of the initial wave traveling from the

generator to the load, while Voltmeter B will read the voltage of the reflected wave traveling in the opposite direction. Voltmeter C will read the sum of the two waves, as it is attached at a point where the two waves are co-existant.

It is necessary that the voltmeters should not introduce any disturbance in the line, and this, together with the low voltages used, dictated the use of vacuum tube voltmeters. These voltmeters have one stage of amplification with a vacuum tube detector operating a d.c. milliameter.



22-TYPE TELEPHONE REPEATER CIRCUIT
TO SHOW ANALYSIS OF WAVES ON A TRANSMISSION LINE

FIG. 3.

In order that the relations along a line may be observed, an artificial line consisting of T sections is used, and the repeater is attached to a plug, so that the magnitude of the waves may be measured at different points. When this plug is moved from the sending to the receiving end, with reflection at the latter, Voltmeter A reading the initial wave will show a reduced reading with increased length, while Voltmeter B will gradually increase its reading. Voltmeter C will vary in amplitude showing maximum and minimum points, *i.e.*, the presence of standing waves due to the varying phase between the two waves.

If the line is terminated in its surge or characteristic im-

pedance, Voltmeter B will read zero at all points along the line, showing the absence of a reflected wave. Voltmeter C will vary in the same manner as voltmeter A since they now read the same wave and will show the absence of standing waves when there is no reflection on the line.

In studying physical phenomena, apparatus which shows instantaneous relations and which can be arrested in its operation from time to time, or can be operated as slowly as desired is of immense help in making the relations vivid to the student. Furthermore, analysis into components is always a potent method of understanding complex phenomena, and the author has found these models extremely useful in this respect.

Optical Model of Heaviside Layer

In these days when Physics is placing more and more emphasis upon wave motion as a fundamental property of matter, wave motion in three dimensions as well as one becomes of great interest. Radio engineers have been devoting a large part of their energy to a study of the manner in which electromagnetic waves are propagated over the face of the earth. The theory of the Kennelly-Heaviside layer assumes a conducting layer at a distance of a number of miles above the surface of the earth, in which the free electrons and ionized condition of the atmosphere cause a variation in the velocity of propagation and therefore a refraction of the wave, and this theory has been well substantiated by experiment and is now generally accepted. This refraction may cause a portion of the wave radiated from an antenna at a high angle with respect to the earth, to bend over and return to the ground at a distance from the transmitter. This assumption explains many phenomena such as the skip distance of short waves, fading, and in fact was first proposed to explain the fact that radio communication is possible at all around the surface of the earth.

By an optical analogy the bending of electromagnetic waves in a medium in which the velocity of propagation varies with height may be shown. A similar model was described inde-

pendently by C. W. Rice in Q. S. T., August, 1927, although the model here described was in operation before that time. However the solutions described there have given better results than any others.

A solution of alcohol and distilled water is placed in the bottom of a glass sided box to about one third the height of the box. A solution of glycerine and alcohol is then allowed to run through a glass tube into the bottom of the box. Each solution contains some Sulphate of Quinine to make a fluorescent. After running in the heavier glycerine, the combination is allowed to stand for at least twenty four hours and diffusion gradually takes place between the two solutions. There is then a gradually varying mixture, and since the index of refraction of the two solutions differs, the velocity of propagation will gradually increase with height. If a beam of light is directed into the box, and refracted at an angle from a mirror on the bottom, the ray of light which starts upward will bend over and return to the base. As the angle of the ray with the base is increased, a critical angle will be reached where the ray is not bent back, and it will be found that there is therefore a minimum distance between the mirror and points on the base which the refracted light may reach. This explains the phenomena of skip distances on short waves, where there is a region surrounding a transmitting station in which no signal is received. This is pronounced at the short waves, because the portion of the energy propagated directly along the surface of the earth is rapidly absorbed.

Acoustic Model of Interference Produced by Heaviside Layer

In the broadcast band and higher wavelengths, the wave traveling along the surface of the earth is not quickly absorbed, and there are two or more paths over which a signal may travel. Since these paths are of different lengths, the two portions of the signal may arrive in or out of phase and may therefore assist or oppose each other. The interference effect may be shown by an accoustic model.

Two telephone receivers are connected by two lengths of

hose providing two paths for sound to travel between them. One length of hose has inserted in its middle a collapsible metal tube so that the distance may be varied through a wavelength. One receiver is excited by a 1,000 cycle oscillator, and acts as a transmitter emitting a wavelength of around fourteen inches. The other receiver picks up the sound and generates an E.M.F., which is applied to a vacuum tube voltmeter.

When the length of one hose connection is varied, the received signal as indicated on this voltmeter will vary between zero and a maximum. The path of a radio wave through the Kennelly-Heaviside layer also varies due to changing conditions and produces some of the fading of radio transmission.

Model of Heterodyne of Sine Waves of Different Frequencies

Interference conditions between two waves of the same frequency may be explained to the student by stationary vector diagrams. When the waves are of different frequencies, it is harder to visualize the relations. But this heterodyne or beat action is a very important principle and as a mechanical model has been constructed to show it. It is illustrated in Fig. 4.

An approximate sinusoidal motion may be produced by connecting to a rotating disk a brass rod which in turn is connected at the other end to a rod constrained to move in one dimension. The latter rod will move with a sinusoidal motion whose frequency is determined by the speed of the disk, one cycle for each revolution. If a similar disk is driven at a different speed it will set up a motion of a different frequency. The ratio of speeds between the two disks may be varied by driving one by a fixed pulley, and the other by a pair of conical pulleys, so arranged that the belt may be shifted.

If the ends of the two rods moving at different frequencies are connected by still another rod, the center of this last rod will execute a motion whose displacement at any instant will be proportional to the sum of the two sine waves. A bead attached at this point will therefore execute a beat motion, the

amplitude for a while being large and then gradually decreasing and increasing again. It will be observed that when the motion is large, the two rods are moving together; while when the amplitude is small, one rod will be moving in one direction when the other rod is moving in the opposite direc-

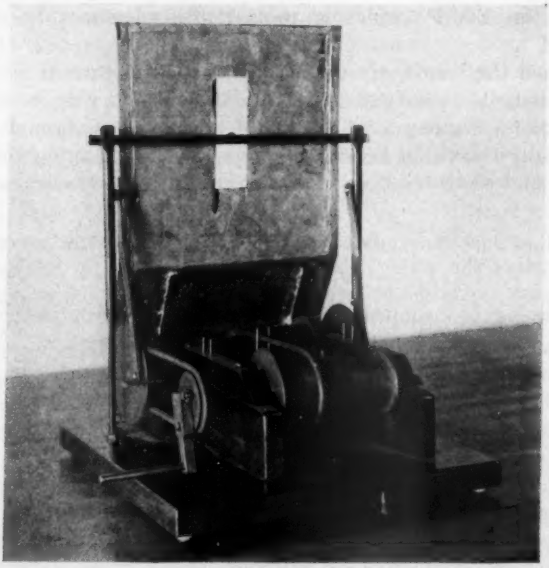


FIG. 4.

tion. The phase relations are therefore brought vividly to the attention of the student.

MODEL SHOWING OSCILLATION OF COUPLED CIRCUITS

After the student has seen the motion which results from the addition of two sine waves he is able to compare it with the motion of a pair of coupled pendulums. Coupled circuits containing inductance and capacity or their equivalent and having two degrees of freedom will have two resonant frequencies.

If such a system is set into free oscillation it will vibrate at both frequencies simultaneously, *i.e.*, the motion will be the sum of two sine waves of different frequency. If the motion of either circuit is observed, the movement will increase and decrease in amplitude in the same way as the heterodyne model illustrated.

An old experiment for showing the motion of coupled circuits is to suspend two pendulums from a slack string. This string will couple the two pendulums together and if one is set in vibration, the characteristic movement will be observed.

Electrical Model Showing Production of Side Bands by Modulation

When one frequency is modulated by another, new frequencies are produced. In radio transmission these new frequencies, equal to the sum and difference of the modulating and modulated frequencies are called side bands. Their existance may easily be proven mathematically, but students are often unconvinced of their physical reality.

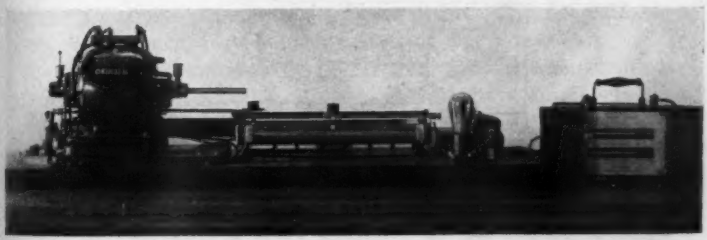


Fig. 5.

The presence of side bands may be shown if two frequencies such as sixty and ten cycles are impressed on a vacuum tube operated so as to give distortion. The ten cycles may be conveniently obtained from a rotary converter such as is used to provide ringing current in telephone exchanges. The output of the vacuum tube is impressed, through a condenser and choke coil filter, to eliminate the D.C. component

of the plate current, upon a vibrating reed frequency meter. Such a frequency meter will show the coexistance of several frequencies by the vibration of one or more reeds. The setup is shown in Fig. 5. The carrier of sixty cycles, and the two side frequencies of fifty and seventy cycles will be plainly evident. If the speed of the rotary converter is gradually reduced and the modulating frequency thereby decreased, the side frequencies will gradually approach the carrier.

Vacuum Tube Characteristic Curves by Cathode-Ray Oscillograph

As has been mentioned, a very important electrical circuit element is the thermionic vacuum tube. The characteristics of an individual tube can be determined by curves showing

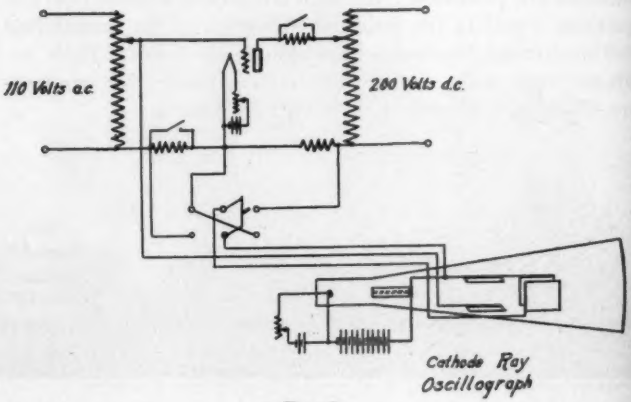


Fig. 6.

the relations between the operating parameters. Of all the characteristic curves of a vacuum tube, probably the most important is the grid voltage-plate current curve. Since there are several independent variables viz., plate voltage, filament current as well as grid voltage, the grid voltage-plate current curve will change with a change in plate voltage and filament current. It is of primary importance in the proper

operation of a tube that the nature of these changes be understood.

The grid voltage-plate current curve may be continuously plotted and shown by means of the Cathode-Ray oscillograph. The Cathode-Ray oscillograph is itself a form of vacuum tube, and shows many interesting properties of electronic flow in a vacuum. The most convenient and commercially available is the Western Electric 224-A tube. In this tube is a hot cathode or filament, and a tubular anode or plate. When a voltage of about 300 volts is applied between the filament and the anode, a flow of electrons will take place, and a portion of the flow will be projected through the small hole in the end of the anode. The tube is so arranged that they can continue on their path for about 20 centimeters before they impinge upon the circular end of the tube. This end is coated with a salt which becomes fluorescent upon the impact of the electrons. The tube is flared so that the circular fluorescent screen is about 10 centimeters across. Shortly after leaving the anode, the electron stream passes between two pairs of deflecting plates. The pairs are at right angles to each other, and by applying potentials between one or the other pair, the electron stream may be deflected along the x or y axis.

The circuit for showing the vacuum tube characteristics is shown in Fig. 6. A 60 cycle A.C. voltage is applied to the grid of the three electrode tube and continually varies the grid voltage. The grid voltage is impressed between the pair of plates which produces the deflection along the x axis. For each instantaneous value of grid voltage there will be a corresponding value of plate current. By introducing a resistance in the plate circuit and connecting the pair of plates which deflects along the y axis across the resistance, the spot of light at any instant will show the plot of grid voltage vs. plate current. The continually varying voltage causes the spot to sweep along the curve so that the eye sees the complete characteristic curve.

By reducing the filament current, the flat top will be seen to drop, showing that this saturation is due to an insufficient emission of electrons. If the plate voltage is increased, the

whole curve will shift to the left, showing the possibility of control by this important parameter.

In operating distortionless amplifiers the grid of a vacuum tube is never allowed to become positive. Distortionless amplification obtained by operating over a portion of the characteristic where there is a linear relation between *voltage at the grid* of the tube and plate current, does not show why distortion occurs when the grid becomes positive, as the curve is still straight on the positive side of the axis. In practice, the voltage applied to the tube usually acts through a high impedance, and if this impedance is connected between the applied voltage and the grid of the tube, and *applied voltage* vs. plate current is plotted, a different curve will result. This new curve will be identical with the first when the grid is negative and takes no current, but as soon as the grid becomes positive, the current flow causes a drop in the series impedance and the curve breaks sharply on the positive side of the y axis, showing that under these conditions the only straight line portion of the curve available for distortionless operation is that on the left or negative side. This may readily be shown on the Cathode-Ray oscillograph set up, for, by cutting in and out a resistance in series with the grid, the sharp break may be observed.

In addition to the particular lesson shown by cutting in the resistance in plotting the curve, another important point illustrated is that, when working out of generators with high internal impedances, more attention must be paid to the details of theory. In applying mathematics to vacuum tubes, they may be considered as generators working with high internal impedances, and many of the relations in amplifiers are modified by this fact. Statements have been made that radio frequency and audio frequency transformers do not obey the regular laws because an increase in turns ratio does not always produce an increased voltage. The regular laws of course hold, but simplifications which can be made when operating out of generators of low impedance, such as neglecting voltage drop due to magnetizing current, cannot be used when the internal impedance is high.

Analog of Acoustic and Electrical Circuits by Acoustic Filters

One of the most potent methods of instruction is by analogs. Human beings reason in terms of past experience, *i.e.*, they think by analogy. Most of the relations in electrical networks correspond to laws met with in mechanical and acoustic vibrations. While in teaching electricity, use is made of Mechanical comparisons, it is interesting to note that the knowledge of complicated wave propagation in electrical networks had so exceeded the corresponding mechanical theory, that the radical improvements made a few years ago in the mechanical phonograph were obtained by reducing all the mechanical constants to resistance, inductance, and capacitance and applying the theory of the Electric Wave Filter. It is well to impress on the Electrical Engineer that his knowledge of alternating currents may be applied to many mechanical problems of vibration.

To show this intimate relation the acoustic wave filter is very useful. This filter is made from pipes and metal cans, and can be accurately designed by anyone who has studied electric filters, and can use a few conversion factors.

To observe the action of the filters, they must be terminated in a suitable load, and an exponential horn can be used which will give a resistance load over a wide range of frequencies. The acoustic filter may be connected between the horn and the driving unit, and when the frequency of the current through the driving unit is varied over a wide range, the pass and stop bands will be noticed. For rapidly varying the frequency of the driving current a beat note oscillator is most convenient.

The filters and horn used were built by Messrs. V. R. Bambeck and G. J. Heinzelman as a senior thesis, and measurements showed the cut off frequency very close to their computed values.

Demonstration of Correct and Incorrect Set ups for Audio Frequency Amplifiers

An interesting network which is operated over a wide band of frequencies is the audio frequency amplifier. Involved in

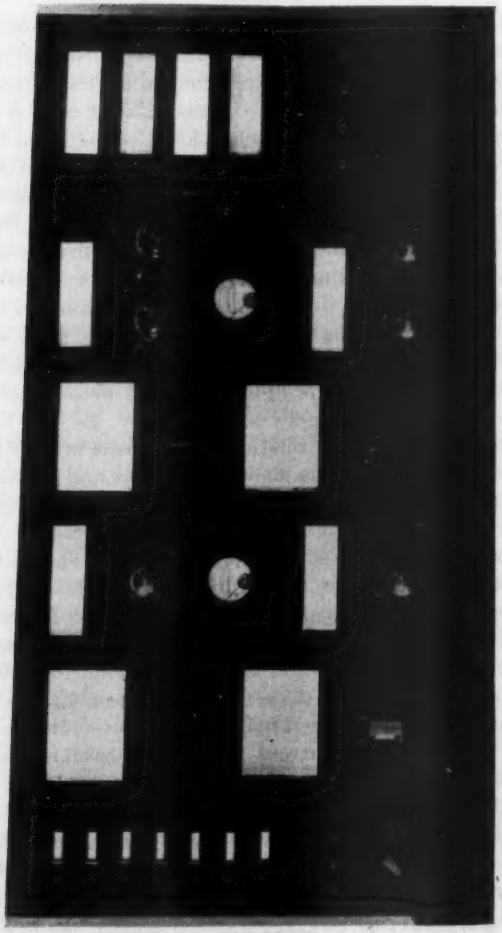


Fig. 7.

such a piece of equipment are the proper operation of vacuum tubes, and the frequency characteristics of transformers. An interesting method of showing the proper and improper relations is to set up an amplifier in which the transformers, and operating parameters of the tubes may be quickly changed by a switch.

Fig. 7 shows the assembled apparatus, and Fig. 8 shows the wiring diagram. In order to make the connections short and

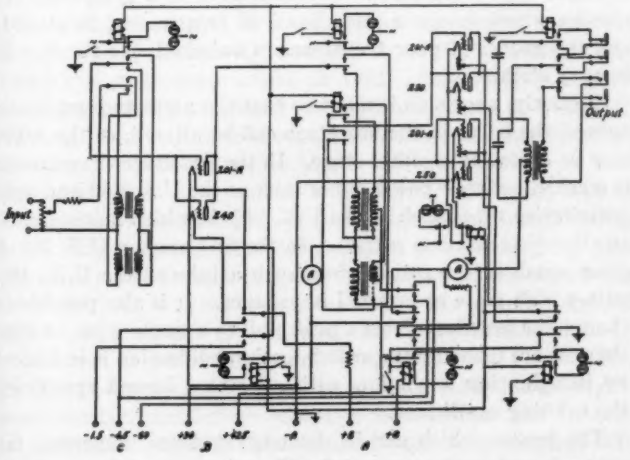


FIG. 8.

reduce extraneous capacities, the change over from one condition to another is made in each case by a relay conveniently located near the tubes and transformers to be switched. The relays are in turn operated by toggle switches at the left of the panel.

The amplifier is a two stage transformer coupled outfit, using a push pull connection in the last stage. Good transformers with a high primary inductance are provided. This high inductance gives a large reactance as a load to the tube, so that the internal drop in the tube will be small down to quite low frequencies and the frequency distortion correspond-

ingly small. For comparison, transformers with low inductance, such as were used a few years ago, are provided; and by throwing a switch these transformers can be substituted in either or both of the stages. Over each transformer, behind an illuminated glass frame, is plotted a curve of amplification vs. frequency. The curve of the particular transformers in use are illuminated.

As excitation an electric pick up with phonograph records is found most convenient. If music, such as a symphony orchestra which covers a wide band of frequencies, is played, and the good and poor transformers switched, the result will be very striking.

Similarly, provision is made so that the plate and grid voltages of the tubes in the last stage can be altered, or the tubes may be switched in either stage. In the last stage the contrast is marked between power tubes such as the U.X. 250 and general service tubes such as the U.X. 201-A, which have a much smaller distortionless output. In the first stage a U.X. 201-A gives much better results than such a tube as the U.X. 240, with a high plate or internal impedance. It is also possible to change the last stage from a push pull to a single tube. As the changes are made by the switch, each modification is indicated by illuminating a window with a printed legend specifying the existing conditions.

The lessons which can be demonstrated are numerous, important, and at the same time entertaining, and it is only by seeing and hearing the results that they can be appreciated. It would prolong this paper too greatly if they were all described in detail.

This paper has been written to show some of the possibilities in the lecture room demonstration of fundamental principles of Physics which have important applications in communication engineering, but which should also be useful in the training of electrical engineers and physicists for service in any field. It is hoped that sufficient variety has been introduced to illustrate the broadness of a field which has been too frequently neglected, or considered specialized.

THE ENGINEERING EDUCATION PROGRAM CALIFORNIA INSTITUTE OF TECHNOLOGY

RALPH W. SORENSEN
Professor of Electrical Engineering

California Institute of Technology is the direct outgrowth of old Throop University, founded as an undergraduate and secondary polytechnic school in 1891. According to its first catalogue of sixteen pages it owed its origin to Amos G. Throop, who "endowed it with his wealth and consecrated *all* his energy to its support." At the time mentioned there were few universities and colleges in Southern California, and no engineering and scientific colleges or schools of manual training. This situation, of course, was in general keeping with the classical education program of the day, little time being devoted in our colleges to the teaching of the so-called applied arts which have now grown to be technical professions.

The self-perpetuating board of trustees who joined Mr. Throop in furthering his plan were far sighted enough to discover the fact that future education must include the "practical" without excluding the "classical" and they specified that the newly founded Institute should furnish all students with a liberal and practical education. This new school set forth on a plan for four college courses, one a scientific course leading to the degree Bachelor of Science. In the detailed description of plans much space in the first catalogues is devoted to describing the Manual Training Department, which was announced as one of the leading departments. This was a radical step for a college to take but a much needed one because at that time there was no such course of instruction west of Chicago. In order that there be no misunderstanding of the ideals of the original board of this University in developing such a course of manual training, I wish to insert the following quotation taken directly from that first bulletin:

"Dr. Woodward says: 'A manual training school is not a school for the training of carpenters, blacksmiths, machinists and mechanical engineers. In a manual training school, properly so-called, no attempt is made to cultivate dexterity at the expense of thought. No mere sleight-of-hand is aimed at, nor is muscular exercise of itself held to be of educational value. An exercise, whether with tools or with books, is valuable only in proportion to the demand it makes upon the mind for intelligent, thoughtful work. In the school shop the stage of mechanical habit is never reached. The only habit actually acquired is that of thinking. No blow is struck, no line drawn, no motion regulated from muscular habit. The quality of every act springs from the conscious will, accompanied by a definite act of judgment.' "

"While 'tis true that the young man or woman who takes the manual training course afterwards masters any one of a score of arts, trades or callings in a few months where the average man or woman requires years, it is far from true that this training is only or chiefly valuable to the boy who is to be a carpenter, a blacksmith, or a draughtsman, an architect, a machinist, an engineer or an artist. For the physician or surgeon no preparatory training is worth more. For the lawyer in this day of endless commercial litigation what preparation is better? For the preacher what training can better fit him to appreciate the condition of the masses of the people? And as 'Learn to do by doing' becomes something more than a fine institute sentiment, such training for the teacher will be indispensable. The man who has to manage large commercial manufacturing or constructive enterprises needs such training for the protection and economic expenditure of his capital, more than the laborer needs it for the winning of his bread."

"Second Annual Announcement of Throop Polytechnic Institute, 1892." (Note the change of name.) This second catalogue, much larger than the first and profusely illustrated with pictures of up-to-date shops and laboratories, is devoted almost entirely to a description of scientific and manual training courses, and of the excellent equipment available for giving work in these courses. The outstanding courses listed were: Biology, Chemistry, Electricity, English, History, Mathematics, and Physics. The list of courses given in the latest bulletin or catalogue of California Institute of Technology differs little from the list of courses to which reference has just been made.

Subsequent catalogues of Throop Polytechnic Institute and its successor, the present Institute, show a steady evolution in educational plan entirely consistent with the growth of the community contingent to the California Institute of Technology and to the educational needs of our nation as a whole. Viewed in the light of American educational history, the most important announcement given in that entire group of catalogues probably was that contained in the supplementary number issued in December, 1908, wherein was declared the change in policy which made Throop Polytechnic Institute strictly a technical college with the highest possible scholastic standards, and separated from it the Academy and Normal School departments. The new technical college in stating its entrance requirements specified the completion, with recommending grades of a thorough high school or preparatory course.

Another unique feature of the Institute has been the absence of specialized engineering courses! the emphasis on fundamentals underlying all such courses; and the large amount of time given to English, History, and allied subjects, which as a rule in America have been much neglected in engineering courses. This type of curriculum was adopted by the Institute because those forming its policies were of the opinion that engineering students were in general becoming too highly specialized without having opportunity to become broadly educated citizens. By 1910 the curricula for the four-year undergraduate course in Civil, Electrical, and Mechanical Engineering were well rounded out and were substantially as now given. The Institute at that time moved from its down town location to its present campus and began work in "Throop Hall" with thirty-one engineering students, a reduction of student body to less than 7 per cent. its former number. From 1910 to the time of the World War the student body growth was slow, uniform, and substantial, and there was throughout that period a general tendency toward increasing entrance requirements, work standards, and quality of work expected.

In 1913 a Department of Chemistry, under the leadership of Doctor Arthur A. Noyes, was opened, and in 1917 the

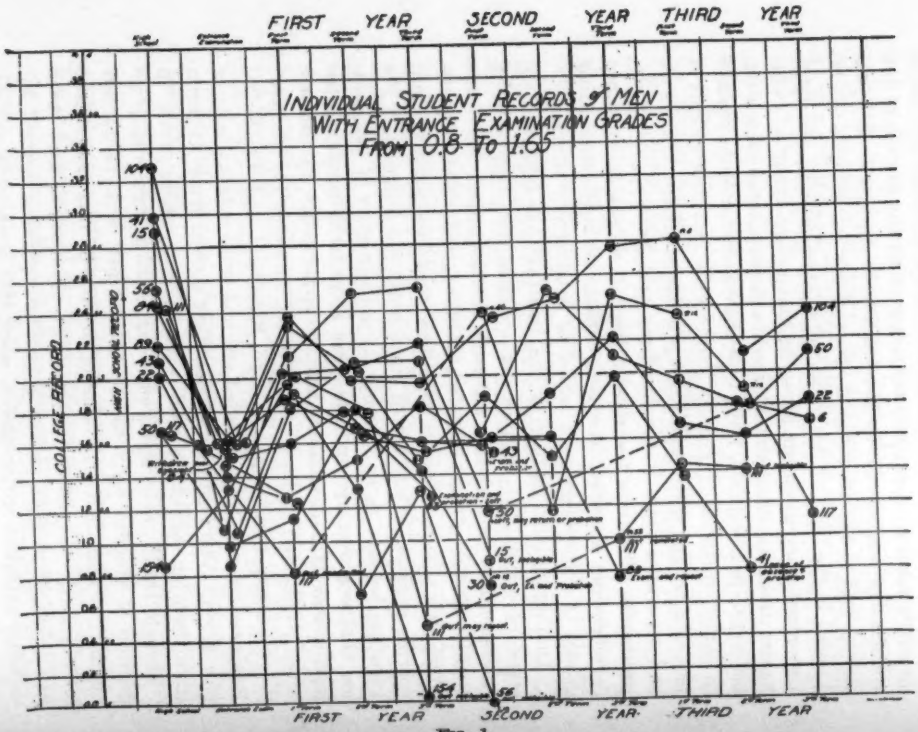
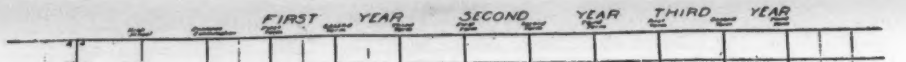

FIRST YEAR
SECOND YEAR
THIRD YEAR
INDIVIDUAL STUDENT RECORDS OF MEN
WITH ENTRANCE EXAMINATION GRADES
FROM 0.8 TO 1.65
COLLEGE RECORD
DECREASING ABILITY
FIRST YEAR
SECOND YEAR
THIRD YEAR

FIG. 1.


FIRST YEAR
SECOND YEAR
THIRD YEAR

FIRST YEAR SECOND YEAR THIRD YEAR

Fig. 1.

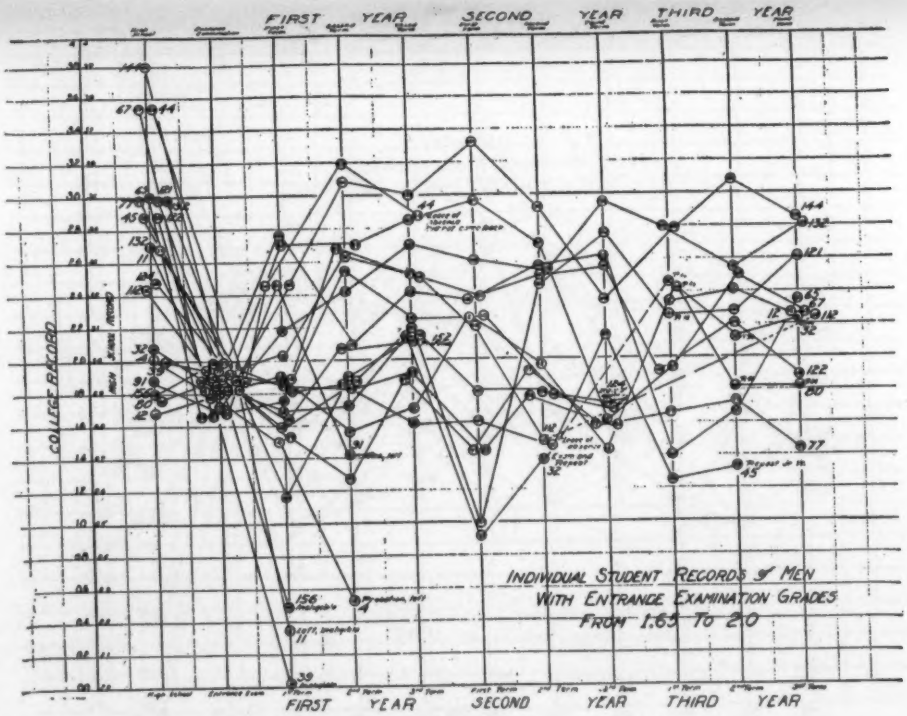

FIRST YEAR SECOND YEAR THIRD YEAR
COLLEGE RECORD
INDIVIDUAL STUDENT RECORDS OF MEN
WITH ENTRANCE EXAMINATION GRADES
FROM 1.65 TO 2.0
FIRST YEAR SECOND YEAR THIRD YEAR

Fig. 2.

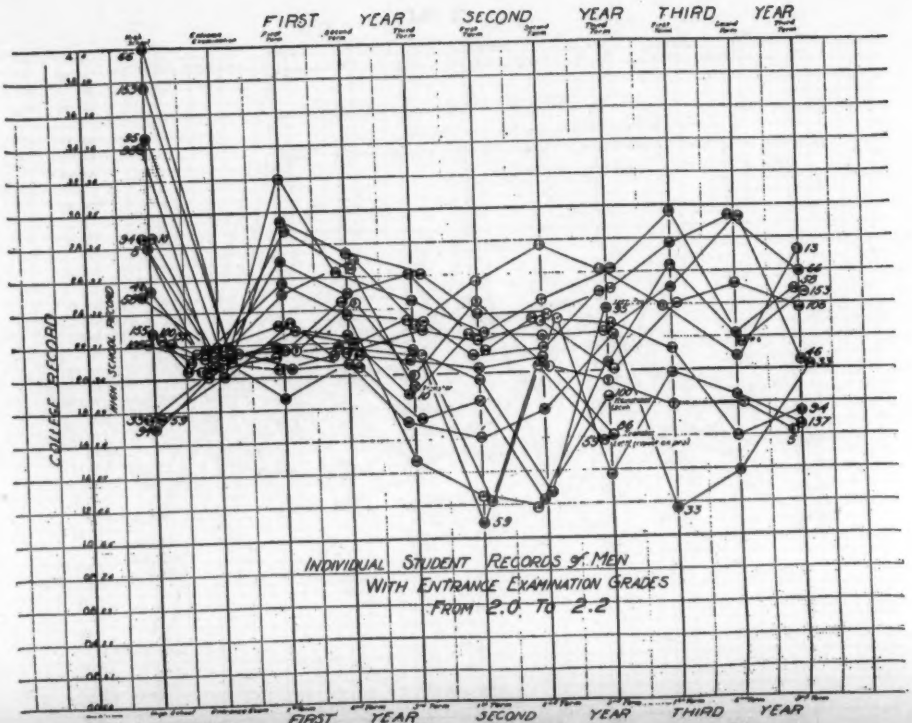
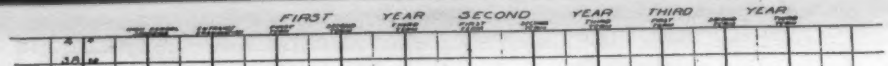

FIRST YEAR
SECOND YEAR
THIRD YEAR
COLLEGE RECORD
HIGH SCHOOL RECORD
INDIVIDUAL STUDENT RECORDS OF MEN
WITH ENTRANCE EXAMINATION GRADES
FROM 2.0 TO 2.2
FIRST YEAR
SECOND YEAR
THIRD YEAR

FIG. 3.


FIRST YEAR
SECOND YEAR
THIRD YEAR

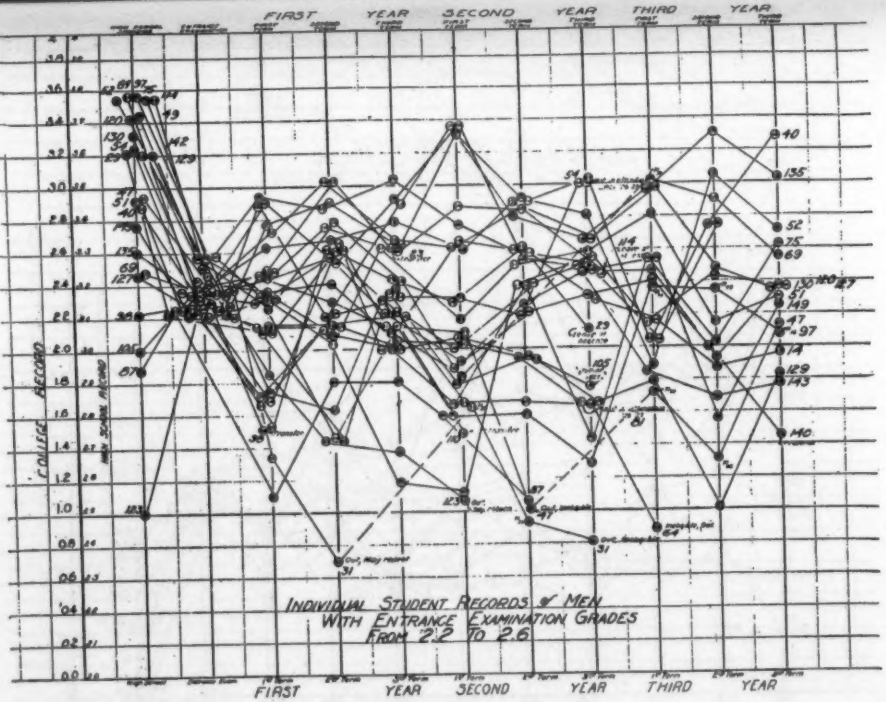

FIRST YEAR
SECOND YEAR
THIRD YEAR
COLLEGE RECORD
HIGH SCHOOL RECORD
INDIVIDUAL STUDENT RECORDS OF MEN
WITH ENTRANCE EXAMINATION GRADES
FROM 2.2 TO 2.6

Fig. 4.

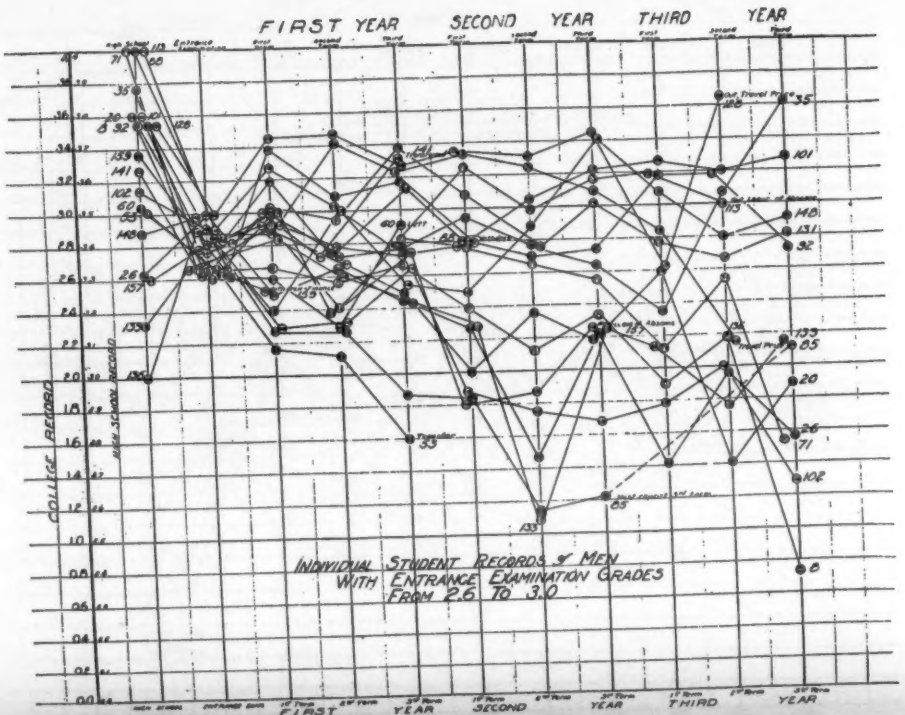

FIRST YEAR
SECOND YEAR
THIRD YEAR
COLLEGE RECORD
HIGH SCHOOL RECORD
INDIVIDUAL STUDENT RECORDS OF MEN
WITH ENTRANCE EXAMINATION GRADES
FROM 2.6 TO 3.0

FIG. 5.

FIRST YEAR
SECOND YEAR
THIRD YEAR

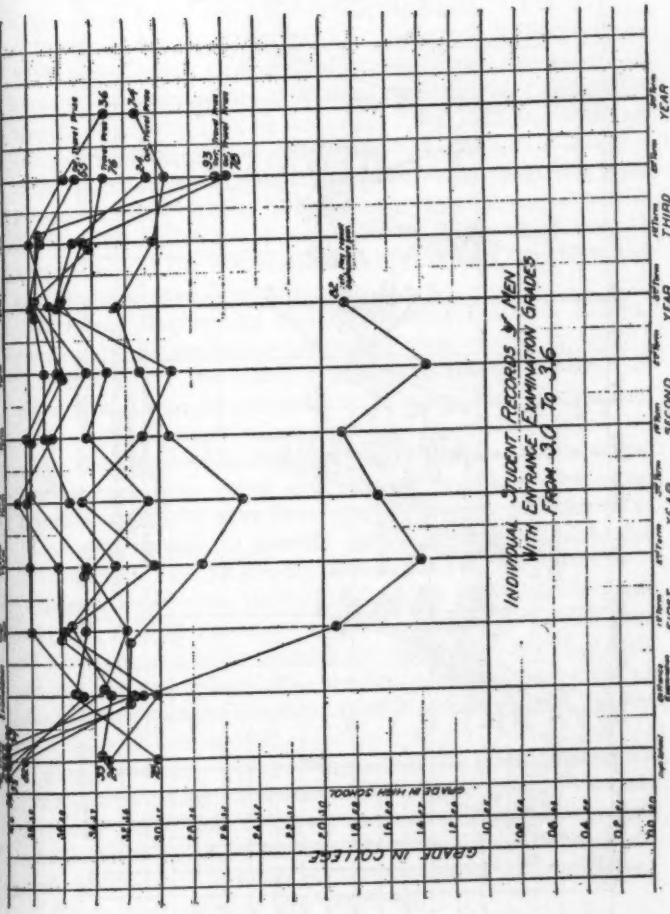

INDIVIDUAL STUDENT RECORDS OF MEN
WITH ENTRANCE EXAMINATION GRADES
FROM 3.0 TO 3.6
GRADE IN COLLEGE
GRADE IN HIGH SCHOOL
FIRST YEAR
SECOND YEAR
THIRD YEAR

FIG. 6.

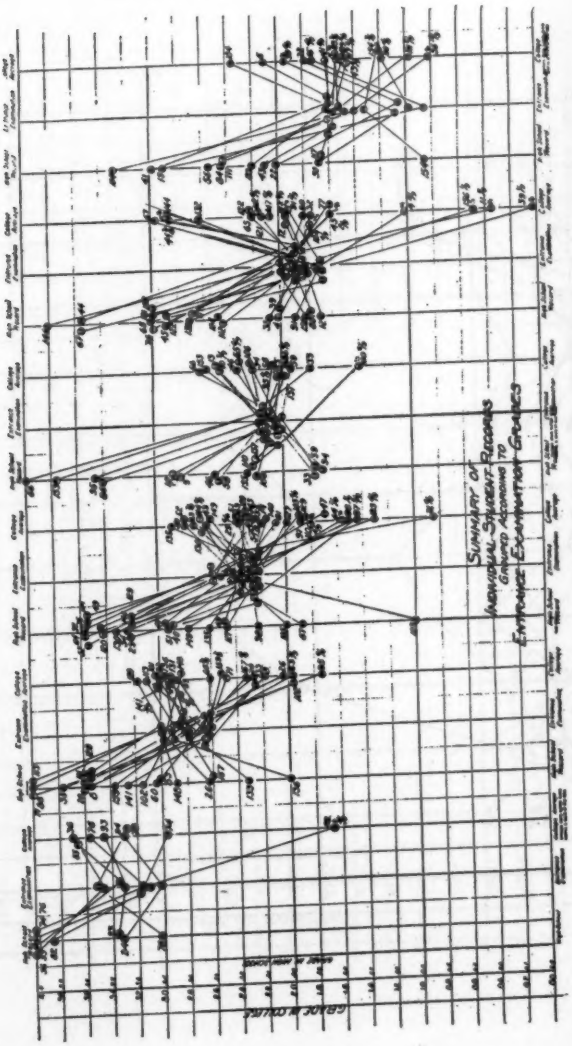

SUMMARY OF
INDIVIDUAL STUDENT RECORDS
GROUPED ACCORDING TO
ENTRANCE EXAMINATION GRADES

FIG. 7.

Gates Chemical Laboratory was erected. This laboratory provided room for a Department of Research in Chemistry, which department was immediately organized.

Doctor Robert A. Millikan first came to the Institute in 1916, and the first unit of the Norman Bridge Laboratory of Physics was erected in 1920, thus permitting a Physics Research Department to be organized. By 1923 the building for this department was completed.

In 1924 the Million Volt Laboratory was completed, thus giving the first special provision for Engineering *research* work. This building was made possible by the whole hearted cooperation of the Southern California Edison Company and the Westinghouse Company.

A steam Engineering and Engineering Research Laboratory, and a Seismological Laboratory were erected in 1927.

Buildings for the Daniel Guggenheim Graduate School of Aeronautics, the Department of Biology, and the Dabney Hall of the Humanities have just been completed.

To these there will be added very shortly complete shops, astrophysics laboratories and research equipment for astrophysics work, and some more student housing facilities so as to provide as soon as possible residence accommodations for all who may wish to live on the campus.

The present name, California Institute of Technology, was adopted in 1920, coincident with the adoption of the new plan of carrying on a large research program. The first doctorate degree was granted in 1921; the first doctorate degree for an engineering student was given in 1927, with two such degrees in 1928, and four in 1929.

Five years ago a change was made in the whole undergraduate plan whereby all special engineering courses were made five-year rather than four-year courses. Also, since that time admission to all undergraduate classes has been by examination, prerequisite to which there still remains the requirement of fifteen recommended high school units.

The present educational policies may be stated briefly as follows: The Institute offers two four-year undergraduate courses, one in Engineering and one in Science, both leading

to the degree, Bachelor of Science. These courses have sufficient similarity to make interchange between them possible without undue difficulty.

The four-year undergraduate course in Engineering is fundamental in character, with a minimum of specialization in the separate branches, and the degree does not refer to any branch of Engineering. This course contains relatively a large amount of work in the basic sciences of Physics, Chemistry, and Mathematics, and about twenty per cent. of the entire four years of the students' time is devoted to cultural studies. By this means the student has opportunity to obtain a basic technical course combining fundamental scientific training with a broad human outlook. Students planning to enter the technical phases of Engineering, such as research and design are expected to take the fifth-year course in the particular field of Engineering chosen—Civil, Mechanical, Electrical, Aeronautical, or Chemical Engineering. A fair proportion of the work of the fifth-year course is allotted to experimental and research work. Throughout the entire course students are closely supervised and a rigorous standard of scholarship, which eliminates all but those who are best fitted to pursue the work of the Institute, is maintained.

Engineering students who show originality and research ability and have completed the fifth year in a satisfactory manner are encouraged to continue their college work until they have obtained the degree Doctor of Philosopsy in Engineering. Advanced courses in mathematics, physics and engi- research problems, are requisites for the doctorate degree. Worthy men in these graduate courses who have ability as teachers or who have shown extraordinary research ability are awarded teaching and research fellowships.

The plan of using graduate students as teachers has presented its own special problems in the conduct of classes and laboratory work, and has shown definitely that not all good students and research men are at the same time good teachers. However, when care is used in selecting such men for teaching positions and in assigning them to the classes for which they are well equipped the results have been a delight to those re-

sponsible for the courses. In general, teaching fellows or student teachers should not be assigned classes too near their own student level. It has been found desirable to start teaching fellows as laboratory assistants on duty with an experienced man in charge. As a rule only men who have done at least one whole year of continuous work subsequent to the course in which he is giving instruction are giving these fellowships; that is, a fifth-year man should supervise student laboratories only for men in the third year or below. Classes or quiz sections are given only to teaching fellows who have had two full years of graduate work, or have had the equivalent in teaching and practical engineering experience. Teaching fellows selected in accordance with this program bring to their classes the enthusiasm of young engineers new to the job who because of recent experiences as students have a sympathy for the student and his work. Men having this sympathy, combined with the enthusiasm of youth, the desire to make good, and educated "up to the job" supplement in an excellent way the more mature type of leadership which has been developed by the older members of the teaching staff, and give to courses a life which might otherwise be lacking.

The reputation of any educational institution is largely determined by the record of its graduates. The quality of these graduates is determined as much or even more by the manner of their selection as by the content of the courses pursued by the student while in residence at any particular institution. Any institution wishing a certain type of student must therefore give careful attention to their selection. As has been stated, all candidates for admission to California Institute of Technology for undergraduate courses must present not less than fifteen recommended high school units, and must pass in a satisfactory manner comprehensive examinations in English, Mathematics, Chemistry, and Physics. These examinations are prepared in such a way as to test the knowledge of fundamental laws which will enable a student to think in terms of Chemistry, Mathematics, and Physics, and express those thoughts in English, rather than to test a memory of certain specific courses which may have been completed in

high school. This method of making a selection of applicants for our freshman class has been in operation only since 1924, but has, to our minds, proven beyond doubt a very satisfactory procedure. As evidence of this, we have noted a relatively very small loss of students at the end of the first term, and a very decided increase in the percentage of entering freshmen graduating at the end of four years. In this connection the following table will be of interest:

CALIFORNIA INSTITUTE OF TECHNOLOGY

Admitted as Freshmen		B.S. degrees conferred			Per Cent of Original Class Graduating at the End of Four Years
Year	Number	Year	Number	Number from Original Class	
1910	16	1914	7	7	44%
1911	18	1915	10	8	45%
1912	23	1916	8	6	26%
1913	25	1917	12	10	40%
1914	45	1918	16	11	25%
1915	66	1919	23	10	15%
1916	85	1920	30	13	15%
1917	97	1921	37	18	19%
1918	213 (S.A.T.C.)*	1922	69	39	18%
1919	149	1923	53	30	20%
1920	138	1924	78	36	26%
1921	149	1925	81	41	28%
1922	162	1926	105	55	34%
1923	170	1927	95	58	34%
1924	114†	1928	69	46	40%
1925	131	1929	86	47	36%

* Student Army Training Corps.
† First Entrance Examinations.

The plan of examination has also been extended to include a comprehensive examination for all students who plan to enter the junior year. This examination covers college Mathematics, Physics, and Chemistry as given in the freshman and sophomore years, and is given to all students who have done the work either at California Institute of Technology or who are transferring from some other college. Our own students

have opportunity for a two-weeks' review near the end of the sophomore year as preparation for these comprehensive examinations. All who do not satisfactorily pass these comprehensive examinations, and transfer students, have opportunity to take a special three-weeks' course just preceding the opening of the fall term, at the conclusion of which comprehensive examinations are again given. These sets of comprehensive examinations may be taken without registration in the special course just mentioned. This plan results in a reduction of student failures during the year to a very small number, and in a rather uniform size of classes during the four years, as will be noted by the undergraduate school enrollment given in the following table:

UNDERGRADUATE SCHOOL ENROLLMENT 1928–29

Seniors: Science: Physics 8; Chemistry 2; Chemical Engineering 12; Geology 8; Mathematics 1	31		
Engineering: Aeronautics 14; Civil Engineering 21; Electrical Engineering 22; Mechanical Engineering 21; General 1	79	110	
Juniors: Science: Physics 15; Chemistry 5; Chemical Engineering 15; Geology 9	44		
Engineering 78; General 1	79	123	
Sophomores: Science	54		
Engineering	67	121	
Freshmen		140	
Special		4	498

In addition to the undergraduate school, the Institute has a relatively large graduate school, the enrollment in which for 1928–29 was 141 students, classified as follows:

GRADUATE SCHOOL ENROLLMENT 1928–29

National and International Research Fellows	14	
Research Fellows of the Institute	8	
Graduate Students: Physics	50	
Chemistry and Chemical Engineering	20	
Mathematics	3	
Geology	16	
Biology	3	
Engineering	27	141

The general plan of administration and teaching at the Institute differs from that of engineering colleges in general on the following points:

A great deal of emphasis is given to the graduate school and to a plan of enabling all students, so far as possible, to undertake research and special problems calling for originality. This requires a large faculty in proportion to number of students; and demands that classes be kept small, thus calling for many sections, each section being limited to approximately twenty men. In following out this plan care is taken to see that the undergraduate work is not neglected for the graduate work, but rather that the undergraduates are mixed with the graduates and encouraged to make contact with them so far as is possible.

There are in general no department heads and no strict classification of departments. In so far as there are departments, each department and its instructors have complete freedom as to manner of conducting courses, keeping attendance records, etc. To avoid difficulty under this plan, schedules are planned on the basis of total hours per week, the average time for the student, including three hours of physical education (required of all undergraduate students), being about fifty-three hours per week. Except in special cases, physical education takes the form of competitive games under special supervision.

Honor Sections

During the first term of the freshman year students are assigned to sections indiscriminately. Subsequent to that the better students in the freshman, sophomore, and senior classes are assigned to the honor section. In the junior year there is an honor section and a special honor section. The special honor section is made up of a few men who by their excellent records of the preceding two years are considered worthy contestants for the junior travel prizes, of which there are two, each carrying an award of nine hundred dollars. These prizes are given the two most worthy students in the junior class as determined upon the basis of a supervised competition. The

prizes are to be used for a trip to Europe between the junior and senior years.

Honor System

The students maintain a very efficient student body government, which has complete control of all student body affairs, operating under a thoroughly effective and satisfactory honor system which applies to their conduct both on and off the campus. Administration of the honor system is entirely in the hands of a Student Board of Control made up of members of the various undergraduate classes. No faculty member participates in the action of this body directly, there being another channel, known as the Student Relations Committee, consisting of ten members of the Faculty and nine students, through which contact is maintained between students and faculty. The student members of this committee are duly elected officers of the student body. If time permitted, many examples of the effective operation of the student honor system could be cited. It is the concensus of opinion of the faculty that under this system student affairs are administrated much more effectively than would be the case with faculty supervision of student conduct.

Intercollegiate Athletics

At California Institute of Technology the entire athletic program is considered as part of the educational program, rather than a student body activity, and as such is wholly under the control of the faculty and Board of Trustees of the Institute. All coaches and members of the athletic staff are regular faculty members appointed by the Executive Council.

The following curves, compiled by Dr. Robert T. Knapp, of our Mechanical Engineering Department, and Mrs. Knapp, showing the relation between high school records, entrance examinations, and standing of students while undergraduates, are presented. It will be noted the first six of the curves show lines, each of which represents a student, drawn from points which represent the student's high school record, to points which represent his grade in the entrance examinations, and thence to points which represent the college grade for each

of the three terms for the first, second, and third years. Each curve sheet represents a group of students, the classification being made according to their standing in the entrance examinations. The maximum possible grade, to agree with our marking system, was called "4." No one was admitted with an entrance examination grade lower than 0.8. The men taking up the class were arbitrarily divided into six groups according to grades, as shown on each of the several curve sheets.

By following the line for any particular student it is possible to observe a relation between the student's high school record, the record made in his entrance examination, and the record made as a student in the Institute.

It will be noted that a number of the better students have no record for the third term of the third year, because that year there were several students with records so close together that a way was provided which enabled the whole high honor section group to participate in the European travel prizes.

As a final curve, there is shown a summary of the several groups making up the class under discussion, such summary giving a comparison of high school record, entrance examination record, and college average record for any particular student.

In conclusion, I do not wish to suggest even that the plan of operation presented in this paper is one which should be considered a universal plan for all technical colleges; in fact, it seems to me quite desirable that all technical colleges should not have identical courses, but rather there should be a considerable variety of courses and requirements.

To meet the demand made of technical men, it is certainly pertinent that there be some technical colleges which, like California Institute of Technology, emphasize graduate and research work, together with a broad education, involving much study of literature and general science, whereby men so desiring may become proficient in a highly technical field and at the same time not deficient in those studies which make for education in a broader sense.

NEW MEMBERS

BLACK, HAYSE H., Assistant in General Engineering Drawing, University of Illinois, Urbana, Ill. H. H. Jordan, R. P. Hoelscher.

CROSBY, LEMUEL S., General Personnel Supervisor, Long Lines, American T. & T. Co., 15 Dey, New York City. R. I. Rees, O. W. Eshbach.

CUNNINGHAM, CHARLES W., Instructor in Civil Engineering, Rutgers University, New Brunswick, N. J. P. H. Daggett, H. D. Hatfield.

HAWTHORN, GEORGE E., Assistant Professor of Civil Engineering, University of Washington, Seattle, Wash. F. M. Warner, E. R. Wilcox.

HORINE, JOHN S., Associate Professor of Drawing, University of Kentucky, Lexington, Ky. C. C. Jett, W. E. Freeman.

HOSTED, EDWARD G., Instructor in Mechanical Engineering, Drexel Institute, Philadelphia, Pa. J. H. Billings, R. C. Disque.

KLUGH, WILLISTON W., Associate Professor of Drawing, Clemson College, Clemson College, S. Car. A. L. O'Banion, S. R. Rhodes.

KOEPKE, CHARLES A., Associate Professor of Industrial Engineering, University of Minnesota, Minneapolis, Minn. R. L. Rhoads, G. H. Sechrist.

MILLINGTON, HOWARD G., Assistant Professor of Mathematics, University of Vermont, Burlington, Vt. J. W. Votey, L. B. Puffer.

MORTON, ROSCOE W., Associate Professor of Mechanical Engineering, Colorado School of Mines, Golden, Colo. M. F. Coolbaugh, J. C. Fitterer.

MOYER, RALPH A., Assistant Professor of Civil Engineering, Iowa State College, Ames, Iowa. A. H. Fuller, T. R. Agg.

O'BANNON, LESTER S., Professor of Heat Engineering, University of Kentucky, Lexington, Ky. W. E. Freeman, C. C. Jett.

PETERSON, ERIC F., Instructor in Engineering, Duluth Junior College, Duluth, Minn. O. M. Leland, Frederic Bass.

PULVER, HARRY E., Associate Professor of Civil and Structural Engineering, University of Wisconsin, Madison, Wis. C. M. Jansky, J. B. Kommers.

SALATHE, ALBERT, Associate Professor of Chemical Engineering, Syracuse University, Syracuse, N. Y. Louis Mitchell, S. D. Sarason.

WILLIAMS, BASSETT G., JR., Instructor in Civil Engineering, Lehigh University, Bethlehem, Pa. Ralph J. Fogg, Paul Cloke.

WRIGHT, HARRY M., Instructor in Practical Mechanics, Purdue University, Lafayette, Ind. J. D. Hoffman, J. H. Porsch.

It is essential for the progress of any organization that new members be added to it continuously. The Council has voted

in 180 new members so far this year. These members come from 64 different institutions. There are 178 institutions listed as having members of the faculties who are members of this Society. This means that there are 114 institutions where there is one or more members in the Society but from which there have been no applications for membership. One new member from each of these institutions would represent a very material growth to the Society for the current year. Listed in this number of the JOURNAL are the institutions and the number of members in each together with the applications which have been received to date. Your institution should be listed among those sending applications. Will you please make this a personal matter and secure at least one new member from your institution at once? There is an application blank in this number of the JOURNAL which you can have one of your colleagues fill out.

1929–30 MEMBERSHIP CAMPAIGN

On September 13 the Secretary wrote to the representative of the Society in each institution in the United States and Canada asking him to send to this office the names of all members of the engineering faculty. On this list the Secretary marked off the names of those persons who were members of the Society and to the others he sent invitations for them to join the Society enclosing an application blank for that purpose. The names of the faculty members of the following institutions were received.

On March 11 when this notice was sent to the printer invitations had been sent to 1,484 persons as indicated on the table. 180 applications have been received to date.

The Secretary asks you to seek the men in your institution who are not members of the Society and to second the invitation which he has extended. If your institution is not listed here, ask your local representative for the reason. We are printing an application blank herewith for the convenience of those who may not have any available.

F. L. BISHOP,
Secretary.

Institution	Application Blanks Sent	Applications Received	Members
Akron, Univ. of	3	0	9
Alabama Poly. Inst	15	3	13
Alabama, Univ. of	13	0	1
Alberta, Univ. of	0	1	3
Antioch College	6	1	5
Arizona, Univ. of	0	0	9
Arkansas, Univ. of	7	0	7
Armour Inst. Tech	22	1	23
Beirut, Univ. of (Syria)	0	1	1
Bombay C. E. College	0	0	1
Bradley Poly. Inst	0	0	2
Brazil-Poly. School of State	0	1	1
British Columbia, Univ. of	0	0	4
Brooklyn Poly. Inst	0	0	18
Brown Univ	0	0	8
Bucknell Univ	10	0	10
Buffalo, Univ. of	0	0	1
Calif. Inst. Tech	26	0	7
Calif., Univ. of	0	0	8
Calif., Univ. of So	0	1	6
Carnegie Inst. of Tech	39	0	21
Case School Applied Science	12	3	29
Catholic Univ	0	0	1

Institution	Application Blanks Sent	Applications Received	Members
Chicago, Univ. of	0	0	1
Cincinnati, Univ. of	33	0	7
Clarkson College	0	0	5
Clemson College	0	3	8
Colby College	0	0	1
Colorado Agri. College	13	0	5
Colorado School Mines	37	1	11
Columbia University	27	4	25
Colorado, Univ. of	29	4	20
Cooper Union	0	1	13
Cornell University	71	4	27
Cornell College	0	0	1
Dartmouth College	0	0	4
Dayton, Univ. of	0	1	5
Delaware, Univ. of	0	0	8
Denison Univ	0	0	2
Detroit University	12	3	11
Drexel Institute	31	4	8
Duke Univ	0	0	9
Duluth Junior College	0	1	1
Ecole Polytechnique	28	1	2
Evansville College	0	1	2
Florida, Univ. of	13	0	11
Franklin and Marshall College	0	0	2
Franklin Union	0	0	2
General Motors Inst	0	0	3
George Washington Univ	0	0	2
Georgia Inst. of Tech	41	1	19
Gettysburg College	0	0	2
Girard College	0	0	1
Harvard University	14	1	13
Haverford College	0	0	1
Hawaii, Univ. of	4	0	2
Howard Univ	0	0	1
Idaho, Univ. of	11	5	12
Illinois, Univ. of	32	5	54
Indiana Univ	0	0	1
Iowa State College	67	3	32
Iowa State University	5	2	23
James Millikan Univ	0	0	2
Johns Hopkins Univ	0	0	2
Kansas State Agri. College	62	11	36
Kansas, Univ. of	31	0	23
Kentucky, Univ. of	0	3	14
Lafayette College	3	1	11
Lehigh Univ	0	1	18
Leningrad Poly. Inst	0	0	1
Lewis Inst	0	0	1
La. Industrial Inst	0	0	3
La. Southwestern Inst	0	0	3
La. State Univ	0	0	2
Louisville, Univ. of	5	0	12
Maine, Univ. of	14	0	23
Manhattan College	0	0	7
Marquette Univ	0	0	5
Maryland, Univ. of	0	0	2

Institution	Application Blanks Sent	Applications Received	Members
Mass. Agri. College	0	0	1
Mass. Inst. Tech.	0	1	43
McGill Univ	0	1	9
Mechanics Inst.	0	0	2
Mexico, Univ. of	0	0	4
Michigan College Mines	16	0	6
Michigan, Univ. of	77	5	48
Michigan State College	0	1	12
Minnesota, Univ. of	39	3	75
Mississippi A. & M.	12	0	4
Mississippi, Univ. of	10	0	3
Missouri School Mines	19	2	12
Missouri, Univ. of	6	0	16
Montana School of Mines	0	0	2
Montana State College	0	0	7
Mt. Allison Univ	0	0	2
Nanking Tech. College	0	0	1
Nebraska, Univ. of	0	0	21
Nevada, Univ. of	18	0	3
Newark College of Eng	16	1	12
New Hampshire, Univ. of	9	1	10
New Haven College	0	0	1
New Mexico A. & M.	6	0	3
New Mexico School Mines	8	0	1
New Mexico, Univ. of	0	0	3
New York, College of City	0	0	6
New York Univ	0	0	16
North Carolina State College	0	0	14
North Carolina, Univ. of	0	1	10
North Dakota Agr. College	13	0	4
Northeastern Univ	0	1	30
Northwestern Univ	0	0	6
Notre Dame, Univ. of	0	0	2
Norwich Univ	0	0	4
Nova Scotia Tech. College	8	0	1
Ohio No. Univ.	0	0	3
Ohio Mechanics Inst.	0	0	2
Ohio State University	25	2	57
Oklahoma A. & M.	0	0	9
Oklahoma, Univ. of	23	0	7
Oregon Agr. College	23	4	16
Pei Yeng Univ	0	0	2
Penna. State College	38	1	37
Penna., Univ. of	0	1	13
Philippines, Univ. of	0	0	1
Pittsburgh, Univ. of	11	2	26
Porto Rico, Univ. of	9	0	3
Pratt Institute	0	8	27
Princeton University	8	2	9
Purdue University	92	6	75
Rensselaer Poly. Inst.	0	0	12
Rhode Island State College	0	0	5
Rice Institute	0	0	4
Rindge Tech. School	0	0	1
Robert College	0	0	1

Institution	Application Blanks Sent	Applications Received	Members
Rochester, Univ. of	0	1	2
Rose Poly. Inst	19	6	8
Royal Military Inst	6	0	0
Rutgers Univ	0	2	12
Saskatchewan, Univ. of	9	0	1
South Dakota School Mines	0	3	8
South Dakota State Coll	6	0	2
South Dakota, Univ. of	0	0	5
Stanford University	23	0	14
Stevens Inst. Tech	12	1	12
St. John's Univ	0	0	1
Swarthmore College	0	1	5
Syracuse Univ	0	1	14
Tangshan Univ	0	0	1
Tennessee, Univ. of	0	0	2
Texas Agri. College	0	0	2
Texas A. & M	45	6	30
Texas College Mines	0	0	1
Texas Tech. College	0	2	8
Texas, Univ. of	25	1	8
Toledo, Univ. of	0	0	3
Toronto, Univ. of	0	0	9
Trinity College	0	0	1
Tufts College	11	0	25
Tulane University	12	0	11
Union College	3	1	9
U. S. Naval Academy	0	2	8
Utah Agri. College	0	0	2
Utah, Univ. of	0	0	5
Vanderbilt University	0	1	6
Vermont, Univ. of	8	2	12
Victoria Jubilee Tech. Inst	0	0	1
Villanova College	0	0	1
Virginia Military Inst	0	0	11
Virginia Poly. Inst	36	2	12
Virginia, Univ. of	0	0	14
Washington State Coll	26	1	10
Washington Univ. (St. Louis)	0	0	9
Washington, Univ. of	0	3	15
Wentworth Institute	0	1	8
West Virginia Univ	0	0	10
Wisconsin, Univ. of	0	5	37
Worcester Poly. Inst	13	2	23
Wyoming, Univ. of	6	1	4
Yale University	0	2	41
Industrial	0	17	
	1,484	180	

Total Membership, December 3, 1929

Individual Members	2,226
Institutional Members	119
	2,345

Return to the Secretary, F. L. Bishop, University of Pittsburgh, Pittsburgh, Pa.

Society for the Promotion of Engineering Education

Date.....

THE UNDERSIGNED desiring to become a member of
THE SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION

hereby agrees to conform to the requirements of membership, if elected, and submits the following:

STATEMENT OF QUALIFICATIONS

Full Christian Name and Surname.....
Print Last Name First Middle

Mailing Address (Number and Street).....

Post Office (City and State).....

Full Title of Professional Position.....
(Title) (Department)

Full Name of Institution.....

(To be Signed by Two Sponsors)

SPONSORS { .....
.....

* The number of applications requested by their representative.

FROM REPORT OF THE PRESIDENT, CARNEGIE CORPORATION OF NEW YORK

The generous stream of gifts and endowments has continued to flow during the year under review, but little has been done to help those human activities of which examples have been given in previous Reports, and which offer to foundations as yet uncreated opportunities that are already great and are steadily increasing. In closing, two instances of the practical possibilities of foundation service of this character may be given. The comparative studies carried out under a grant from the Carnegie Corporation by the Society for the Promotion of Engineering Education has brought out clearly that industry in England relies almost wholly upon her technical schools below the professional level for the trained personnel required in production and operation. Here in the United States, the well-equipped institutions of this type are few in number, and while some of them do excellent work, as a whole they play a very minor part in our industrial life. Meanwhile, the recent study of engineering education has made clear that of the 65,000 young men now in engineering colleges fully one-half will not find their permanent careers in any technological position in the production of our industries. These industries could absorb annually thousands of men with the training given in the British schools, and a foundation permanently equipped to study the needs and opportunities of our technical institutes and to give generous financial help when and where it is most needed, might perform a service of great value to the community.

The second need is even greater. It is a commonplace that a man buying an automobile today pays about half the price he would have had to pay a few years ago, and gets twice as good an article. If, however, he has to build a home, he will find the conditions just about reversed. The only reason for this absurd situation is that one industry has

profited by first-rate scientific and engineering thought, and the other has not. It certainly cannot be laid to the rising cost of material and labor, since this has affected both industries alike. Here again a foundation devoted to the study of housing problems and equipped to experiment in different types of design and construction would have the chance to make a contribution of inestimable significance toward the improvement of present conditions.

COLLEGE NOTES

Massachusetts Institute of Technology.—A miniature alternating-current power network, constructed for the extensive solution of problems arising in the design and operation of large power networks has recently been put into operation in the Electrical Engineering Research Laboratory of the Massachusetts Institute of Technology. The Network Analyzer, as this device is called, consists of numerous adjustable units, each adopted to represent some part of a system, and is of such size and flexibility that practically any power network containing as many as 8 generating stations, 60 lines or other connecting apparatus, and 40 loads can be set up and studied. By simple measurement such quantities as current, voltage, phase angle and power can be determined, which are the counterparts of the corresponding quantities on the power system. Thus the problems which can be solved otherwise only with excessive labor and time, are rapidly and easily computed.

This equipment was developed and built jointly with the General Electric Company, and is used both as a research tool in educational work and as a means of solving actual power network problems. The need for this apparatus is being demonstrated by its already extensive use by consulting power engineers and engineers connected with public utility and manufacturing concerns.

The University of Pennsylvania.—Dr. Robert H. Fernald, Whitney Professor of Dynamical Engineering and Director of the Mechanical Engineering Department at the University of Pennsylvania, has been appointed Dean of the Towne Scientific School of the University, it was announced by Provost Josiah H. Penniman. The appointment became effective February 1.

Since the retirement of Dr. John Frazer in 1928, Edward

T. Grandlienard, Professor of Civil Engineering, has been serving as acting Dean of the Towne Scientific School. Dr. Fernald's appointment follows recent action of the University's Trustees in relieving Professor Grandlienard of his administrative duties in order that he may devote his entire time to teaching.

SECTIONS AND BRANCHES

The **Colorado Branch** met on Thursday, January 16, for the annual oyster supper, having as guests Mr. Frank Shepard, who is in charge of the U. S. mint, in Denver, and Messrs. Robert Temple, junior and senior—Engineers of Denver.

After supper the Branch, the students in the College of Engineering, and friends in Boulder, heard a discussion of engineering progress by Mr. Shepard; a discussion of the principles of the Temple Driver, by Mr. Temple, senior; and saw a demonstration of the driver, by Mr. Temple, junior.

Evolved during the war to throw mortar bombs without flash or noise, this powder-actuated driver has been turned to peace time uses, such as repairing damages below waterline on ships, steel-pinning structural parts and joints, and mining coal.

In his talk, Mr. Temple, senior, captivated his audience with his charming manner, stimulated their imagination by his fresh inquisitiveness, and, finally, made everyone feel foolish by talking about fracture velocity, pressure in tons per square inch inside a tube he held in his hand, and about the unstable cohesion of atoms in *steel.*

The audience watched a small steel projectile, driven by eight grains of completely combusted black powder, penetrate a ⅞ inch boiler plate without recoil, flash, or noise—save the click of the firing pin and the impact of the projectile. (A pressure of twenty-eight tons was required to force it out.) One looked at the pin in the plate and felt like remarking, "It didn't happen."

Over one hundred members of the **Purdue University** teaching staff attended the January 7th meeting of the local branch of S. P. E. E.

The subject of discussion was "Is Our Grading System Satisfactory?" The affirmative side of the question was up-

held by Professor R. B. Wiley, Civil Engineering, and Professor T. E. Mason, Mathematics. The speakers for the negative were Professor R. G. Dukes, Applied Mechanics, and Professor J. D. Hoffman, Practical Mechanics.

Professor Wm. Marshall was chairman of the meeting and led the general discussion which followed the presentation of the arguments by the regular speakers.

THE JOURNAL OF HIGHER EDUCATION

Attention is called to the initiation of a new magazine, *The Journal of Higher Education*. It is a journal devoted to the presentation of the educational problems of colleges and professional schools. It has a board of associate editors, each representing one of the great fields of knowledge or one of the professional schools. The publisher is The Ohio State University Press. The manager is W. E. Pearce. The journal is issued under the editorship of W. W. Charters. The assistant editors are W. H. Cowley and Josephine MacLatchy. The journal is issued ten times a year and the cost is $3.00.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, APPLIED MECHANICS DIVISION

In connection with the annual meeting of the American Society of Mechanical Engineers in New York City, December 2–6, 1929, a dinner was held by the Division of Applied Mechanics at which the topic of discussion was the training of men in Applied Mechanics. The chairman of the Division, Mr. G. M. Eaton, presided.

Mr. B. L. Newkirk, of the General Electric Co., and Mr. J. Ormonroyd, of the Westinghouse Electric and Manufacturing Co., discussed the question of the demand in industry for men with special training in Applied Mechanics. They were in agreement that there is a strong and growing demand for such men and that the number of men with aptitude in this field who will secure the special training that is needed is

for some time to come likely to be fewer than will be needed to supply the demands of the industries.

On the subject of a curriculum for a student who is specializing in Applied Mechanics, Professor S. Timoshenko, of the University of Michigan, outlined the special courses now being offered at that institution. There was discussion by Professors J. A. Dent, of the University of Pittsburgh; J. A. Hall, of Brown University; E. O. Waters, of Yale University, and W. Rautenstrauch, of Columbia University. There seems to be agreement with the comments of the last mentioned to the effect that the need of additional facilities for training in Applied Mechanics calls for special provision at a few universities rather than efforts in this direction in engineering schools and universities generally.

BOOK REVIEW

How to Wind D.C. Armatures. By W. E. Hennig. Bruce Publishing Company. 205 pages.

This book covers the field of armature windings for D.C. machines in an exceptionally clear manner.

The illustrations are in multiple color, making them much easier to follow.

After each type of winding has been thoroughly taken up in detail, the author makes a table of conditions that must be met to have that particular type.

The problems and examples in chapters eight and nine are very instructive and thorough.

This book should find a place as a reference book both for schools and for the practical armature winder, also for trade schools.

P. E. R.

FOREIGN SERVICE

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF EDUCATION
WASHINGTON

March 5, 1930.

DR. F. L. BISHOP, Secretary,
Society for the Promotion of Engineering Education,
University of Pittsburgh,
Pittsburgh, Pennsylvania.

Dear Dr. Bishop:

We are informed through the Department of State that applications for the appointment as Scientific Research Officer in the Irrigation Branch of the Punjab Public Works Department, India, may be submitted by properly qualified Americans. The appointment is based on a five-year agreement and the annual compensation will range between 1,735 and 2,095 pounds sterling. Applications should be addressed to the High Commissioner for India, at London, and should in no case arrive in England later than April 19, 1930. I am therefore asking if you will kindly give this information such publicity as you see fit.

Cordially yours,

BESS GOODYKOONTZ,
Acting Commissioner.

(Extract from application blank)

Give names and addresses of at least two persons, preferably in Great Britain, to whom reference may be made as to (a) character and (b) competency.

Have you received any gratuity in respect of service under:

(I) Government in India?

(II) Any other Government?

Are you now in receipt of a pension from any Government?

(Details and amounts must be stated in each case.)

Here give a brief history of your career in chronological order under the following headings. Dates should be stated throughout:

(*a*) Schools or Colleges at which educated. Full particulars should be furnished of honours, certificates, etc., gained.

(*b*) Particulars of subsequent experience, giving names of individuals, firms or institutions by whom employed, the kind of work upon which engaged and salary received.

(*c*) Details of war service, if any.

(*d*) Particulars of any serious illness suffered.

(*e*) Particulars of any knowledge of languages other than English.

Work which must be undertaken by the Research Organization in the near future

1. Methods which must be adopted to reclaim the large areas of land which have been damaged by alkaline salts brought to the upper layers of the soil by the rise of the subsoil water-table, and to prevent their increase.

2. The question of absorption losses from the canals and subsidiary channels is another important problem which calls for further experimental work in order to supply more precise data than is available at present, and allied to this is the determination of the means to be adopted for checking such losses.

3. Problems connected with the flow and distribution of water for irrigation which have been awaiting solution for many years, and in which research is urgently required.